Initial Reports of the Deep Sea Drilling Project

Volume XC, Part 1

Noumea, New Caledonia to Wellington, New Zealand
December 1982—January 1983

NATIONAL SCIENCE FOUNDATION
National Ocean Sediment Coring Program

NSFSP—90

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Drilling locations

Leg	Location	Sites
Phase 1 1968–1970		
1	North Atlantic	1–7
2	North Atlantic	8–12
3	South Atlantic	13–22
4	Central Atlantic	23–31
5	North Pacific	32–43
6	North Pacific	44–60
7	Central Pacific	61–67
8	Central Pacific	68–75
9	Central Pacific	76–84
Phase 2 1970–1972		
10	Gulf of Mexico	85–97
11	North Atlantic	98–108
Re-entry trials		109–110
12	North Atlantic	111–119
13	Mediterranean	120–134
14	Central Atlantic	135–144
15	Caribbean	146–154
16	Central Pacific	155–163
17	Central Pacific	164–171
18	North Pacific	172–182
19	North Pacific	183–193
20	North Pacific	194–202
21	Coral Sea	203–210
22	Indian Ocean	211–218
23	Arabian Sea	219–230
24	Indian Ocean	231–238
25	Indian Ocean	239–249
Phase 3 1972–1975		
26	Indian Ocean	250–258
27	Indian Ocean	259–263
28	Antarctic	264–274
29	Tasman Sea	275–284
30	South Pacific	285–289
31	North Pacific	290–302
32	North Pacific	303–313
33	North Pacific	314–318
34	South Pacific	319–321
35	South Pacific	322–325
36	South Atlantic	326–331
37	North Atlantic	332–335
38	Arctic	336–352
39	Atlantic	353–359
40	South Atlantic	360–365
41	South Atlantic	366–370
42A	Mediterranean	371–378
42B	Black Sea	379–381
43	North Atlantic	382–387
44	North Atlantic	388–392
44A	North Atlantic	393–394
IPOD I 1975–present		
45	North Atlantic	395–396
46	North Atlantic	396A–396B
47	North Atlantic	397–398
48	North Atlantic	399–406
49	North Atlantic	407–414
50	North Atlantic	415–416
51A	North Atlantic	417–417A
51B	North Atlantic	417B–417D
52	North Atlantic	417D–418A
53	North Atlantic	418A–418B
54	Central Pacific	419–429
55	North Pacific	430–433
56	North Pacific	434–437
57	North Pacific	438–441
58	North Pacific	442–446
59	North Pacific	447–451
60	North Pacific	452–461
61	Central Pacific	462
62	North Pacific	463–466
63	North Pacific	467–473
64	Gulf of California	474–481
65	Gulf of California	482–485
66	Central Pacific	486–493
67	Central Pacific	494–500
68	Central Pacific	502–503
69	Central Pacific	504–505, 501
70	Central Pacific	506–510, 504B
71	South Atlantic	511–514
72	South Atlantic	515–518
73	South Atlantic	519–524
74	South Atlantic	525–529
75	South Atlantic	530–532
76	North Atlantic	533–534
77	Caribbean	535–540
78	North Atlantic	541–543, 395A, B
79	North Atlantic	544–547
80	North Atlantic	548–551
81	North Atlantic	552–555
82	North Atlantic	556–564
83	Central Pacific	504B
84	Central Pacific	565–570
85	Central Pacific	571–575
86	North Pacific	576–581
87	North Pacific	582–584
88	North Pacific	581
89	Central Pacific	585–586, 462A
90	South Pacific	587–594

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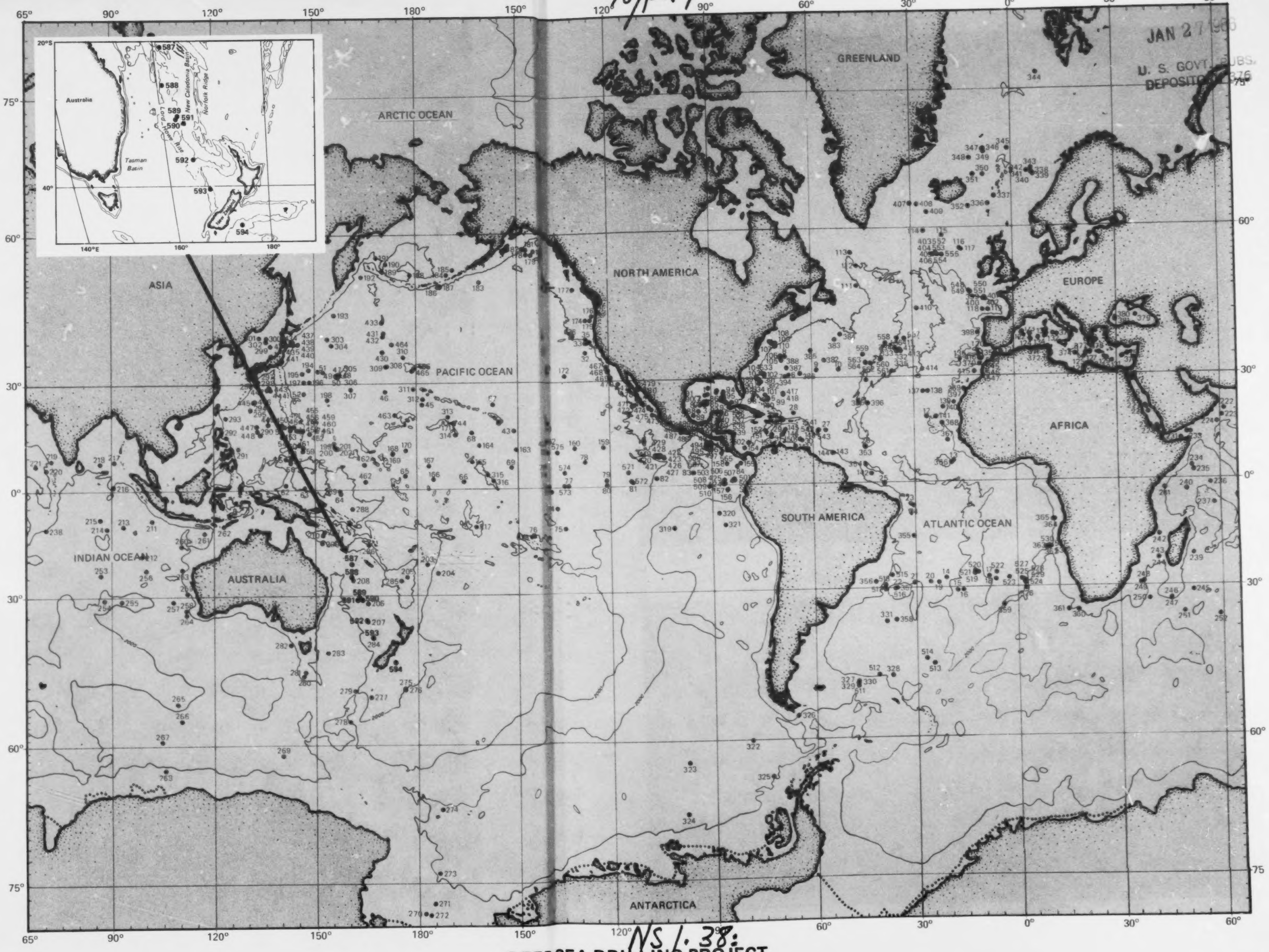
20°S
Australia
Tasman Basin
Lord Howe Rise
New Caledonia Basin
Norfolk Ridge
587
588
589
590
591
592
593
594
40°
140°E
160°
180°
ARCTIC OCEAN
GREENLAND
ASIA
NORTH AMERICA
EUROPE
PACIFIC OCEAN
AFRICA
INDIAN OCEAN
AUSTRALIA
SOUTH AMERICA
ATLANTIC OCEAN
ANTARCTICA
65°
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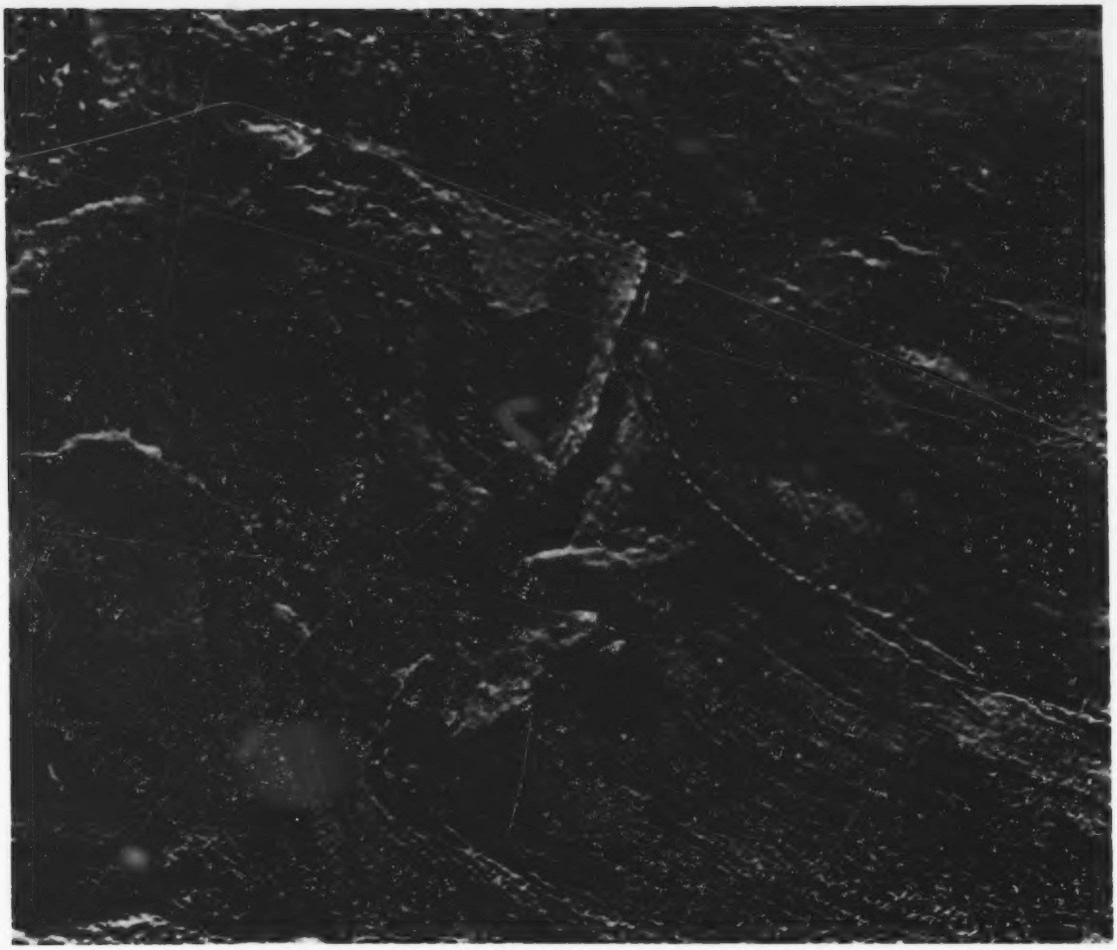
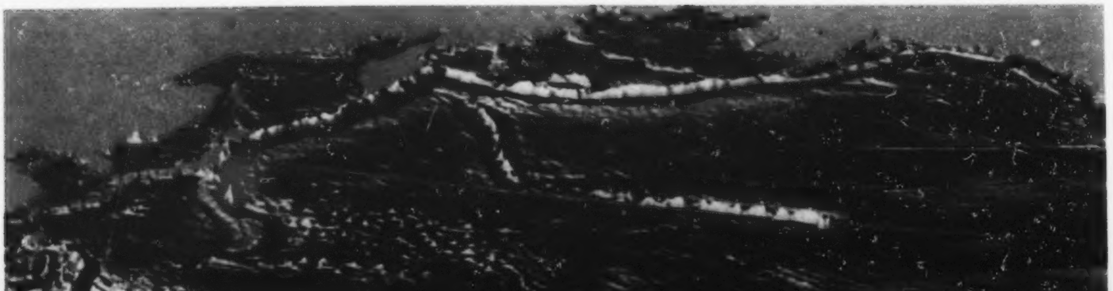
DEEPSEA DRILLING PROJECT

Topographic relief maps of portions of the Pacific and Southern Oceans taken from the Seasat oceanographic satellite. Maps represent the gravitational effect of tectonic features upon topographic relief of the sea surface. DSDP Leg 90 sites were cored on the Challenger Plateau and Lord Howe Rise, shown as a light-colored, curving topographic prominence in the Tasman Sea between the west of New Zealand and the west of New Caledonia. Site 594 was drilled south of the Chatham Rise, shown to the east of New Zealand's South Island. Photos courtesy of William Haxby, Lamont-Doherty Geological Observatory.





Initial Reports
# of the
Deep Sea Drilling Project

A Project Planned by and Carried Out With the Advice of the
JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES)

VOLUME XC, Part 1

covering Leg 90 of the cruises of the Drilling Vessel *Glomar Challenger*
Noumea, New Caledonia, to Wellington, New Zealand
December 1982–January 1983

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Prepared for the
NATIONAL SCIENCE FOUNDATION
National Ocean Sediment Coring Program
Under Contract C-482
By the
UNIVERSITY OF CALIFORNIA
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This material is based upon research supported by the National Science Foundation under Contract No. C-482.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

It is recommended that reference to the whole or to part of this volume be made in one of the following forms, as appropriate:

Kennett, J. P., von der Borch, C. C., et al., 19__. *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

Elmstrom, K. M., and Kennett, J. P., 19__. Late Neogene paleoceanographic evolution of Site 590: southwest Pacific. *In* Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office), ___-___.

Effective Publication Dates of DSDP *Initial Reports*

According to the International Code of Zoological Nomenclature, the date of publication of a work and of a contained name or statement affecting nomenclature is the date on which the publication was mailed to subscribers, placed on sale, or when the whole edition is distributed free of charge, mailed to institutions and individuals to whom free copies are distributed. The mailing date, *not the printed date*, is the correct one.

Mailing dates of the more recent *Initial Reports of the Deep Sea Drilling Project* are as follows:

Volume 79—November, 1984
Volume 80—March, 1985
Volume 81—January, 1985
Volume 82—June, 1985
Volume 83—April, 1985
Volume 84—May, 1985

Printed January 1986

Library of Congress Catalog Card Number 74—603338

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock Number 038-000-00561-8

Foreword

The world's first major oceanographic expedition took place between 1872 and 1876. This expedition, aboard the H.M.S. *Challenger* covering nearly 70,000 nautical miles and gathering oceanographic data from 362 stations, expanded our knowledge of the ocean and provided a solid foundation for future studies in marine geology. A century later, another vessel also named *Challenger* continued to expand our knowledge of the world's ocean and helped revolutionize our concepts of how the seafloor and the continents form and change. The drilling vessel *Glomar Challenger* sailed the same waters as its historic counterpart, seeking answers to new questions concerning the history of our planet and the life it supports. The continued advancement of knowledge about the fundamental processes and dynamics of the earth is leading to a greater understanding of our planet and more intelligent use of its resources.

Since 1968, the Deep Sea Drilling Project (DSDP) has been supported by the National Science Foundation, primarily through a contract with the University of California which, in turn, subcontracted to Global Marine Incorporated for the services of the D/V *Glomar Challenger*.

Through contracts with Joint Oceanographic Institutions, Inc. (JOI, Inc.), the National Science Foundation supported the scientific advisory structure for the project and funded predrilling geophysical site surveys. Scientific planning was conducted under the auspices of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). The JOIDES advisory group consisted of over 250 members who made up 24 committees, panels, and working groups. The members were distinguished scientists from academic institutions, government agencies, and private industry all over the world.

In 1975, the International Phase of Ocean Drilling (IPOD) began. The IPOD member nations, Federal Republic of Germany, Japan, United Kingdom, Soviet Union, and France, partially supported the project. Each member nation actively participated in the scientific planning of the project through membership in JOIDES. Scientists from these countries also took part in the field work aboard the D/V *Glomar Challenger* and postcruise scientific studies.

The first ocean coring operations for the Deep Sea Drilling Project began on August 11, 1968. During the ensuing years of drilling operations in the Atlantic, Pacific, and Indian oceans, the Gulf of Mexico, Caribbean Sea, Mediterranean Sea, and Antarctic waters, the scientific objectives that had been proposed were successfully accomplished. Primarily, the age of the ocean basins and their processes of development were determined. The validity of the hypothesis of seafloor spreading was firmly demonstrated and its dynamics studied. Emphasis was placed on broad reconnaissance and testing the involvement of mid-oceanic ridge systems in the development of the ocean basin. Later legs of the *Challenger's* voyages concentrated on the nature of the oceanic crust, the sedimentary history of the passive ocean margins, sediment dynamics along active ocean margins, and other areas of interest. The accumulated results of this project have led to major new interpretations of the pattern of sedimentation and the physical and chemical characteristics of the ancient oceans.

Technological advances have provided new tools which in turn have opened new dimensions of scientific discovery. The introduction of the Hydraulic Piston Corer in 1979 permitted virtually undisturbed cores of soft sediment layers to be obtained. This technological advance has greatly enhanced the ability of scientists to study ancient ocean environments, as recorded by sediment characteristics and flora and fauna preserved in these deposits.

A second major advance has been the use of the hole after drilling. The project routinely logged holes and performed geophysical and geochemical studies before, during, and after drilling. Long-term downhole geophysical seismic monitoring devices have been implanted successfully in DSDP holes. These new listening devices and geophysical studies have provided valuable information about the origin and nature of the dynamic processes of plate tectonics.

These reports contain the results of the initial studies of the recovered core material and the associated geophysical information. All the world's people benefit either directly or indirectly from this fundamental research. Knowledge about past and present conditions and processes are the foundations for future predictions and developments. Both short- and long-term benefits are obtained by advances in drilling technology and instrumentation. Information is being obtained about the origin and geographic distribution of natural resources. Just as the H.M.S. *Challenger* had a profound impact on scientific thought for over a century, this second *Challenger* expedition has given a greater understanding of the oceans and the processes that form and shape the earth.

Erich Bloch,
Director

Washington, D.C.

Preface

Recognizing the need in the oceanographic community for scientific planning of a program to obtain deep sedimentary cores from the ocean bottoms, four of the major oceanographic institutions that had strong interests and programs in the fields of marine geology and geophysics formed, in May 1964, the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). This group, Lamont-Doherty Geological Observatory; Rosenstiel School of Marine and Atmospheric Science, University of Miami; the Scripps Institution of Oceanography, University of California at San Diego; and the Woods Hole Oceanographic Institution, expressed an interest in undertaking scientific planning and guidance of the sedimentary drilling program. It was the purpose of this group to foster programs to investigate the sediments and rocks beneath the deep oceans by drilling and coring. The membership of this original group was later enlarged in 1968 when the University of Washington became a member, and again in 1975 when University of Hawaii Institute of Geophysics, the Oregon State University School of Oceanography, the University of Rhode Island Graduate School of Oceanography, and Texas A&M University Department of Oceanography became members. In accordance with international agreements, institutions of participating nations became members of JOIDES. Thus, during 1974 to 1976, the Bundesanstalt für Geowissenschaften und Rohstoffe of the Federal Republic of Germany, the Centre National pour l'Exploitation des Océans of France, the Natural Environment Research Council of the United Kingdom, the University of Tokyo of Japan, and Academy of Sciences of the USSR became JOIDES members.

Through discussions sponsored by the JOIDES organization, with support from the National Science Foundation, Columbia University's Lamont-Doherty Geological Observatory operated a drilling program in the summer of 1965, on the Blake Plateau region off Jacksonville, Florida.

With this success in hand, planning began for a more extensive deep sea effort. This resulted in the award of a contract by the National Science Foundation to the Scripps Institution of Oceanography, University of California at San Diego for an eighteen-month drilling program in the Atlantic and Pacific oceans, termed the Deep Sea Drilling Project (DSDP). Operations at sea began in August 1968, using the now-famous drilling vessel, the *Glomar Challenger*.

The goal of the Deep Sea Drilling Project is to gather scientific information that will help determine the age and processes of development of the ocean basins. The primary strategy is to drill deep holes into the ocean floor, relying largely on technology developed by the petroleum industry.

Through the efforts of the principal organizations and of the panel members, who were drawn from a large cross section of leading earth scientists and associates, a scientific program was developed.

Cores recovered from deep beneath the ocean floor provide reference material for a multitude of studies in fields such as biostratigraphy, physical stratigraphy, and paleomagnetism that afford a new scope for investigating the physical and chemical aspects of sediment provenance, transportation, deposition, and diagenesis. In-hole measurements, as feasible, provide petrophysical data to permit inference of lithology of intervals from which no cores were recovered.

A report, describing the core materials and information obtained both at sea and in laboratories onshore, is published after the completion of each cruise. These reports are a cooperative effort of shipboard and shore-based scientists and are intended primarily to be a compilation of results which, it is hoped, will be the starting point for many future new and exciting research programs. Preliminary interpretations of the data and observations taken at sea are also included.

Core materials and data collected on each cruise will be made available to qualified scientists through the Curator of the Deep Sea Drilling Project, following a Sample Distribution Policy (p. xvii) approved by the National Science Foundation.

The advent of *Glomar Challenger*, with its deep-water drilling capability, is exceedingly timely. It has come when geophysical investigation of the oceans has matured through 20 to 30 years of vigorous growth to the point where we have some knowledge about much of the formerly unknown oceanic areas of our planet. About one million miles of traverses have been made which tell us much about the global pattern of gravity, magnetic and thermal anomalies, and about the composition, thickness, and stratigraphy of the sedimentary cover of the deep sea and continental margin. The coverage with such data has enabled the site selection panels to pick choice locations for drilling. The knowledge gained from each hole can be extended into the surrounding area. Detailed geophysical surveys were made for most of the selected locations prior to drilling.

The earth sciences have recently matured from an empirical status to one in which substantial theories and hypotheses about major tectonic processes are flourishing. Theories about the origin of magnetic fields and magnetic reversals, about ocean floor spreading and continental drift, and about the thermal history of our planet have led to specific predictions that could be tested best by an enlightened program of sampling of deep sea and continental margin sediments and underlying rocks.

In October 1975, the International Phase of Ocean Drilling (IPOD) began. This international interest, and the true participation of both the scientists and governments of a number of nations, are eloquent testimony to the importance of the work being done by the Deep Sea Drilling Project.

The members of JOIDES and DSDP and the scientists from all interested organizations and nations who have served on the various advisory panels are proud to have been of service and believe that the information and core materials that have been obtained will be of value to students of earth sciences and to all humanity for many years to come.

Deep Sea Drilling Project

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University of Hawaii, Hawaii Institute of Geophysics

University of Miami, Rosenstiel School of Marine and Atmospheric Science

Natural Environment Research Council, London

Oregon State University, School of Oceanography

University of Rhode Island, Graduate School of Oceanography

Texas A&M University, Department of Oceanography

University of Tokyo, Ocean Research Institute

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[1] Includes member organizations during time of cruise.

[2] This institution and its committees and panel members were noncontributing members of JOIDES at time of cruise.

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[1] Membership at time of cruise.

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SAMPLE DISTRIBUTION POLICY*

Distribution of Ocean Drilling Program and of Deep Sea Drilling Project samples is undertaken in order to (1) provide support to shipboard scientists in achieving the scientific objectives of their cruise, and support shorebased investigators who are preparing contributions to DSDP and ODP reports; (2) provide individual investigators with materials to conduct detailed studies beyond the scope of ODP reports; (3) provide paleontological reference centers with samples for reference and comparison purposes; and (4) provide educators with samples for teaching purposes.

Funding for sample-related activities must be secured by the investigator independently of requesting the samples.

The Ocean Drilling Program Curator is responsible for distributing samples and for preserving and conserving core material. The Curator, who may accept advice from chairmen of the appropriate JOIDES advisory panels, is responsible for enforcing the provisions of this sample distribution policy. He is responsible for maintaining a record of all samples that have been distributed, both onboard ship and subsequently from the repositories, indicating the recipients and the nature of investigations proposed. This information is available to interested investigators on request.

Every sample distributed from the ship or from a repository is labeled with a standard identifier, which includes leg number, hole number, core and section numbers, and interval within the section from which the sample was removed. It is imperative that this standard identifier be associated with all data reported in the literature, and that residues of the sample remain labeled throughout their lives, so that later workers can relate the data to the cores.

Distribution of sample materials is made directly from the repositories (Lamont-Doherty Geological Observatory, Scripps Institution of Oceanography, or Texas A&M University) by the Curator or his designated representative.

1. *Distribution of Samples for Research Leading to Contributions to ODP Reports*

Any investigator who wishes to contribute to the reports of a scheduled cruise may write to the Curator, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A., in order to request samples from that cruise. Requests for a specific cruise must be received by the Curator at least TWO MONTHS in advance of the departure of that cruise, in order to allow time for the review of the request in conjunction with other requests, so that a suitable shipboard sampling program can be assembled. The request should include a statement of the nature of the proposed research, size and approximate number of samples required to complete the study, and any particular sampling technique or equipment which may be required. Requests will be reviewed by the staff representative and co-chief scientists of the cruise and by the Curator. Approval/disapproval will be based upon the scientific requirements of the cruise as determined by the appropriate JOIDES advisory panel(s). The scope of a request must be such that samples can be processed, that proposed research can be completed, and that the paper can be written in time for submission to the relevant ODP cruise report.

Except for rare, specific instances involving ephemeral properties, the total volume of samples removed during a cruise-related sampling program will not exceed one-quarter of the volume of core recovered, and no interval will be depleted. One-half of all recovered materials will be retained in the archives in as pristine a condition as is practicable. Investigators requesting shipboard samples of igneous materials may receive a maximum of 100 igneous samples per cruise.

Because many sample requests are received for shipboard work and because the time of the shipboard party is at a premium, co-chief scientists are strongly urged to limit shipboard sampling to the minimum necessary to accomplish the cruise objectives. Shorebased investigators whose requests for cruise-related samples are approved should expect that they will receive the samples after the cores are returned to the repository, and should schedule research activities accordingly.

Co-chief scientists may invite investigators who are not cruise participants to perform special studies of selected core samples in direct support of shipboard activities. If this occurs, the names and addresses of these investigators and details of all samples loaned or distributed to them must be forwarded to the Curator, via the ODP Staff Representative to that cruise, immediately after the cruise. These investigators are expected to contribute to the cruise reports as though they had been cruise participants. All requirements of the Sample Distribution Policy apply.

Any publication of results other than in ODP reports within twelve (12) months of completion of the cruise must be approved and authored by the whole shipboard party and, where appropriate, shorebased investigators. After twelve months, individual investigators may submit related papers for open publication provided they have already submitted their contributions to ODP reports. Investigations which are not completed in time for inclusion in ODP reports for a specific cruise may be published in a later edition of ODP reports; however, they may not appear in another journal until the ODP report for which they were intended has been published.

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*Revised October 1984

2. *Distribution of Samples for Research Leading to Publication Outside of the DSDP and ODP Reports*

A. Researchers who wish to use samples for studies beyond the scope of the DSDP or ODP reports should obtain sample request forms from the Curator, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A. Requestors are required to specify the quantities and intervals of core required, to make a clear statement of the nature of the proposed research, to state the time which will be required to complete the work and to submit results for publication, and to specify funding status and the availability of equipment and space for the research.

Additionally, if the requestor has received samples from ODP or from DSDP previously, he/she will be required to account for the disposition of those samples by citing published works, six (6) copies of which must be sent to the Curator. If no report has been published, this requirement can be fulfilled by sending a brief (two or three page) report of the status of the research. Unused and residual samples should be returned and data should be sent to the Curator if the project has terminated. Paleontological materials may be returned either to the Curator at ODP or to one of the designated paleontological reference centers. If material is returned to a reference center, notify the Curator when it is sent.

Requests for samples from researchers in industrial laboratories will be honored in the same manner as those from academic organizations. Industrial investigators have the same obligations as other investigators to publish all results promptly in the open literature and to provide the Curator with copies of all reports published and of all data acquired in their research.

In order to ensure that all requests for highly desirable but limited samples can be considered together, approval of requests and distribution of samples will be delayed until twelve (12) months after completion of the cruise or two (2) months after official publication of the core descriptions, whichever occurs earlier. The only exceptions to this policy will be made for specific requests involving ephemeral properties. Requests for samples may be based on core descriptions published in ODP reports produced by the shipboard party, copies of which are on file at various institutions throughout the world. Copies of original core logs and data are kept on open file at ODP, and at the repositories at Lamont-Doherty Geological Observatory and at Scripps Institution of Oceanography.

B. Most investigations can be accomplished handily with sample volumes of 10 ml or less. Investigators must provide explicit justification of requests for larger sample sizes or for frequent intervals within a core. Requests which exceed reasonable size or frequency limits will require explicit justifications and more time to process, and are unlikely to be granted in their entirety.

Requests for samples from thin layers, from stratigraphically important boundaries, from sections which are badly depleted or in unusually high demand may be delayed in order to coordinate requests from several investigators or while the Curator seeks advice from the community. Investigators who submit such requests may expect to receive suggestions for alternative sampling programs or that they join a research consortium which will share the samples. In any event, such exceptional requests will require more time for processing than will more routine requests.

Investigators who wish to study ephemeral properties may request a waiver of the waiting period; however, such requests will be referred automatically to the relevant co-chiefs. If approved, the investigator will join the shore-based contributors to the shipboard science effort, and will incur the obligations thereof (see section 1).

C. Samples will not be provided until the requestor assures the Curator that funding for the proposed research is available or unnecessary. If a sample request is dependent in any way upon proposed funding, the Curator is prepared to provide the proposed funding organization with information on the availability (or potential availability) of suitable samples.

D. Investigators who receive samples incur the following obligations:

(1) To publish significant results promptly; however, no contribution may be submitted for publication prior to twelve (12) months following the termination of the relevant leg unless it is approved and authored by the entire shipboard party.

(2) To acknowledge in all publications that the samples were supplied through the assistance of the international Ocean Drilling Program and others as appropriate.

(3) To submit six (6) copies of reprints of all published works to the Curator, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A. These reprints will be distributed to the repositories, to the ship, to the National Science Foundation, and to the Curator's reprint file.

(4) To submit all final analytical data obtained from the samples to Data Base Manager, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A. Please consult recent issues of the JOIDES Journal or call (409-845-2673) for information on acceptable data formats. Investigators should be aware that they may have other data obligations under NSF's Ocean Science Data Policy or under relevant policies of other funding agencies which require submission of data to national data centers.

(5) To return all unused or residual samples, in good condition and with a detailed explanation of any processing they may have experienced, upon termination of the proposed research. In particular, all thin sections and smear slides manufactured onboard the vessel or in the repositories are to be returned to the Curator. Paleontological materials may be returned either to the Curator at ODP or to one of the designated paleontological reference centers.

Failure to honor these obligations will prejudice future applications for samples.

E. Cores are available for examination by interested parties at the repositories. Investigators are welcome to visit the repositories in order to inspect cores and to specify sample locations when that is required for their research; however, time and space in the workrooms are limited, so advance appointments are required. Occasionally, the space may be fully booked several weeks in advance, so investigators are urged to call for appointments well ahead in order to avoid disappointment. Only the Curator or his delegate may actually remove samples from the cores.

F. A reference library of thin sections, smear slides, and archive photographs is maintained in the repositories for the use of visting investigators. All thin sections and smear slides produced onboard the ship or in the repositories belong to this library.

3. *Distribution of Samples to Paleontological Reference Centers*

As a separate and special category of repository activity, selected samples are being distributed to paleontological reference centers, where the prepared material may be studied by visitors. As of this writing (mid-1984), Foraminifera and Calcareous Nannofossils can be viewed; Radiolaria and Diatoms will be prepared in the future. The present centers are Scripps Institution of Oceanography, California (W. R. Riedel, tel. 619-452-4386); Basel Natural History Museum, Switzerland (J. B. Saunders, tel. 061-25.82.82); and New Zealand Geological Survey, Lower Hutt, New Zealand (A. R. Edwards, tel. 699.059). Future centers are likely to include Texas A&M University, College Station, Texas (S. Gartner, tel. 409-845-8479); Smithsonian Institution, Washington, D.C.; Lamont-Doherty Geological Observatory, Palisades, New York; and an as yet undesignated center in Japan.

Further details concerning the paleontological reference centers are reported periodically in the JOIDES Journal.

4. *Distribution of Samples for Educational Purposes*

Samples may be available in limited quantities to college-level educators for teaching purposes. Interested educators should request application forms from the Curator, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A. Requestors are required to specify preferred sample size and location, to make a very clear statement of the nature of the coursework in which the samples will be used, to explain how the core samples will be prepared and how they will be used in the classroom, to explain in detail why they cannot use similar materials derived from outcrops or dredge hauls (it is NOT acceptable to argue that it requires less effort for the requestor to obtain samples from ODP than to assemble them from other sources), and to certify that funds are available to prepare the materials for classroom use. In general, only samples of materials which are abundant in the collection and which are in little demand for research purposes should be requested for educational purposes. The Curator will not approve requests for materials which are limited in supply or for which demand (real or potential) is great, including most paleontological materials.

5. *Distribution of Data*

The Deep Sea Drilling Project and the Ocean Drilling Program routinely capture much of the data generated onboard ship and published in Program reports. Additionally, data supplied by investigators who have received samples are incorporated into the data bases, so data sets which are larger than can be published are available to investigators. Magnetics, downhole logging, seismic reflection, bathymetric data, and other data collected by the drilling vessel become available for distribution to investigators at the same time as core samples.

At least through mid-1986, DSDP data will continue to be distributed by the Data Base Manager, Deep Sea Drilling Project, A-031, University of California, San Diego, California 92093, U.S.A. A charge will be made to recover expenses in excess of $50.00 incurred in filling individual requests. If required, estimates of charges can be furnished before the work is performed. As DSDP phases down, DSDP data will be available primarily from the National Geophysical Data Center, Boulder, Colorado.

Requests for ODP data should be addressed to the Data Base Manager, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843-3469, U.S.A. Many varieties of DSDP data will be included in ODP data bases. Information on sources of DSDP data will be available from the ODP Data Base Manager.

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ACKNOWLEDGMENTS

The success of Leg 90 of the Deep Sea Drilling Project was due to the dedication and skill of many individuals, a few of whom are noted here. We thank Robert Douglas, who guided the JOIDES Ocean Paleoenvironmental Panel, and Edward Winterer, Chairman of the JOIDES Planning Committee, for their assistance during the planning stage. Karl Hinz and Fred Davey kindly provided some single and multichannel seismic data of use during site selection.

At sea, Captain Joseph Clarke and the crew of the *Glomar Challenger* were at all times most helpful in assuring the success of Leg 90. Special thanks go to David Huey, DSDP Cruise Operations Manager, for his constant sound advice, his sense of humor, and his skill and tenacity in the first successful deployment of the Extended Core Barrel (XCB) that contributed so much to the quality of the cores recovered.

The total length of core recovered during Leg 90 was in excess of 3700 m, the record for DSDP, and a length equal to eight times the height of the Empire State Building. The processing of so much core material required considerable hard work and endurance by the shipboard scientific party, including the technical staff headed by laboratory officer Dennis Graham, and including marine technicians Craig Hallman, Blair McKay, Will Sooter, and Thomas Witte; curatorial representative Robert Hayman; and photographer Victor Sotelo. We thank them. Yeoperson Joanne Collins was most efficient and helpful in processing the voluminous shipboard reports.

We also wish to thank Yves Lancelot, Melvin Peterson, and Matt Salisbury of DSDP headquarters, La Jolla, for being so helpful during the entire Leg 90 period of planning, execution, and publication.

We are particularly indebted to Jan Blakeslee for her high level of professionalism and hard work toward the preparation of these volumes. She was assisted by Carol Bertling, Mary Young-Tardiff, Virginia Roman, and Alice Thompson, among others.

At the University of Rhode Island JPK was assisted in a number of ways by Tom Glancy, Nancy Meader, Robin Ross, and Karin Nelson.

The authors and editors of this volume thank the following scientists (and several others who chose to remain anonymous) for performing critical reviews of manuscript published herein:

Paul Baker; Jack Baldauf; John Barron; Keir Becker; David Bukry; Lloyd Burckle; Bruce Corliss; Fred Duennebier; A. A. Ekoale; David Fisher; P. Gaemers; Steve Gartner; Joris Gieskes; James Gill; A. M. Gombos; J. R. Hein; Thomas Janacek; David Johnson; Lloyd Keigwin; Gerta Keller; D. B. Kent; Tom Loutit; William Melson; Kenneth Miller; Joseph Morley; James Natland; Catherine Nigrini; S. Norton; Neil Opdyke; William Orr; Amanda Palmer; Martin Palmer; K. Perch-Nielsen; S. F. Percival; Nicklas G. Pisias; Richard Poore; Warren Prell; Johanna Resig; Detmar Schnitker; Cynthia Shaw; Bernie Simoneit; Lisa Tauxe; T. L. Vallier; Ted Van Vleet; Herman Zimmerman.

PART I: INTRODUCTION

1. INTRODUCTION AND OBJECTIVES, TECHNIQUES, AND EXPLANATORY NOTES[1]

Shipboard Scientific Party[2]

INTRODUCTION AND OBJECTIVES

Deep sea drilling has provided the materials necessary for the relatively new study of paleoceanography, which is concerned with the development of ocean systems through geologic time. Paleoceanography includes studies of the development of surface circulation, the history and effects of bottom-water circulation patterns, planktonic and benthic biogeographic development and rates of organic evolution, the history of biogenic productivity and its effects on sediment distribution, and the history of calcium carbonate and siliceous deposition and dissolution. All of these fields are interrelated. The early stages in evolving Cenozoic paleoceanography have seen the development of a general scenario in which the warm Mesozoic oceans have been replaced by cold oceans with bottom waters close to freezing, a pattern which has created strong environmental gradients between the tropics and the poles.

The global climatic changes did not proceed uniformly, but in a stepwise manner, punctuated by discrete and sudden coolings which seem to have resulted from marked changes in the geometry of the ocean basins and associated changes in ocean circulation. One of the most prominent changes took place near the Eocene/Oligocene boundary (38 Ma) when the cold, deep water of the oceans developed following the onset of ice formation around Antarctica. Subsequent coolings occurred during the middle Miocene (15 Ma) when much of the ice seems to have accumulated in the east Antarctic ice sheet, the latest Miocene when substantial west Antarctic ice sheets may have accumulated, and the late Pliocene (around 2.5 Ma) when Northern Hemisphere ice sheets began to develop, perhaps in response to the closing of the Central American Seaway (Isthmus of Panama). Present-day patterns have been established only recently and have often been significantly modified by the repeated climatic oscillations associated with glacial–interglacial episodes.

DSDP Leg 90 successfully obtained a traverse of high-quality middle to upper Cenozoic cores between equatorial and northern subantarctic water masses in the southwest Pacific (Fig. 1, Table 1). This suite of cores was obtained using the hydraulic piston corer (HPC) and the extended core barrel (XCB) systems in order to provide higher core recovery and better-quality sections that are much less disturbed than standard rotary cores formerly obtained in this area by DSDP. The XCB, which was first successfully used during Leg 90, is a core barrel that extends several centimeters beyond the main rotary drill bit, ensuring a less disturbed drilling environment ahead of the main water jets of the drill bit (see description under Techniques). It is used to core sediments after they have become too consolidated for use of the HPC. Most of the sites drilled during Leg 90 employed a combination of HPC and XCB, and core recovery was both high (average of about 90%) and of good quality.

Leg 90 is one of several DSDP legs that were set up to complement each other for global paleoceanographic investigations. Others are Leg 68 (Caribbean, Gulf of Panama), Legs 72–76 (South Atlantic), Leg 85 (eastern equatorial Pacific) and Leg 87 (northwest Pacific). All were aimed at greater understanding of global paleoceanographic change and thus required continuous sequences exhibiting relatively high sedimentation rates. Sites were selected in areas exhibiting greater sediment thickness rather than the thin sediment cover characteristic of the early days of deep sea drilling, when basement rocks and overlying basal sediments were prime objectives. Furthermore, a pair of HPC holes was taken at each location to provide a better chance of complete recovery of the sediment section for high-resolution stratigraphic and paleoceanographic work.

Seven main sites and one minor site were cored during Leg 90 (Fig. 1, Table 1). A ninth site (Site 586) was drilled at the northern extremity of this same traverse during Leg 89 and is discussed in Leg 89 and Leg 90 *Initial Reports*. The nine sites are placed along a latitudinal transect to obtain paleoceanographic records for a number of distinct water masses and to maximize our ability to make correlations across the wide latitudes between equatorial and subpolar regions.

The physical oceanography of the modern southwest Pacific is still not well known. Knox (1970) has summarized the position of the several surface water mass

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

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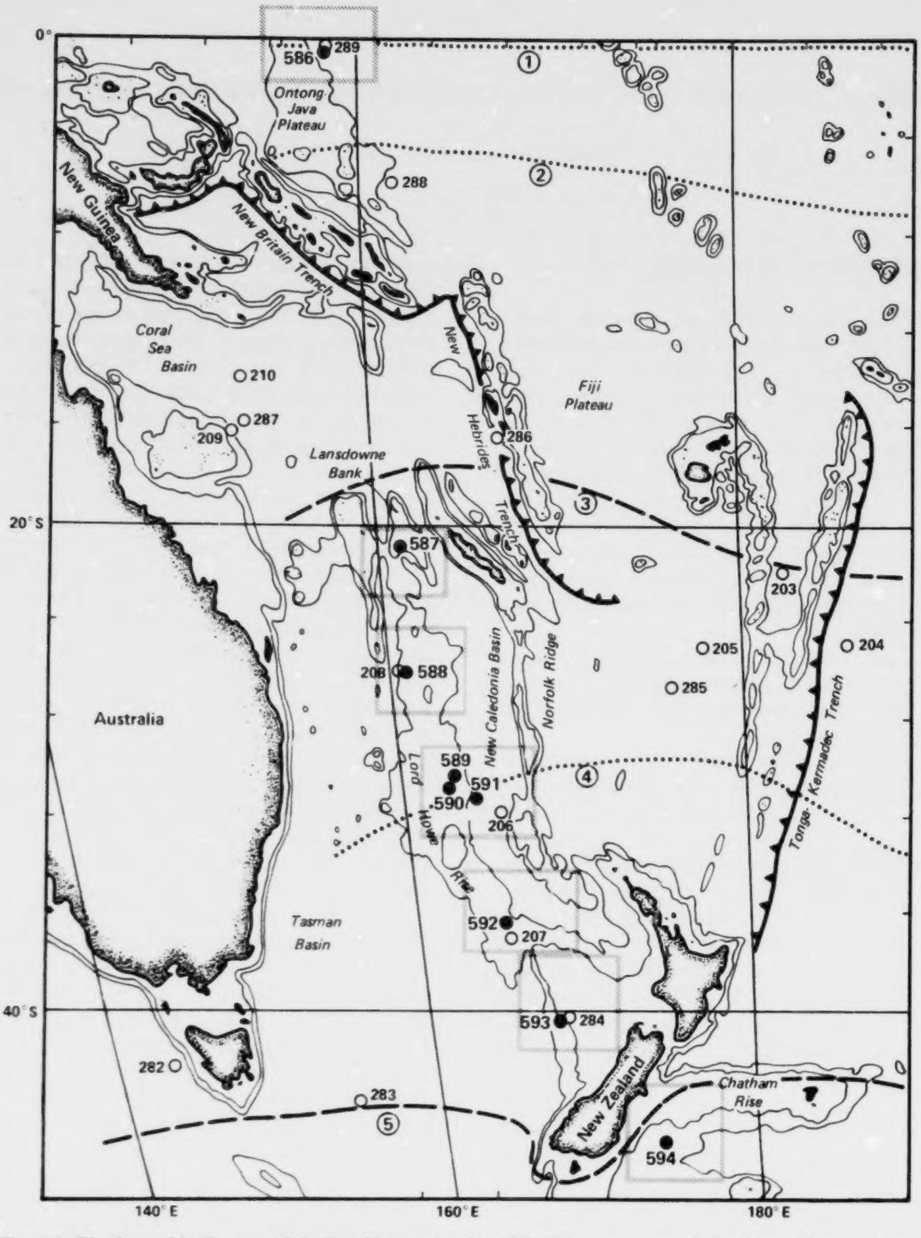
0°
20°S
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140°E
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586
289
Ontong-Java Plateau
①
288
②
New Guinea
New Britain Trench
Coral Sea Basin
210
287
209
Lansdowne Bank
New Hebrides Trench
286
Fiji Plateau
③
587
203
205
204
208
588
285
New Caledonia Basin
Norfolk Ridge
Australia
589
591
590
206
④
Lord Howe Rise
Tonga-Kermadec Trench
Tasman Basin
592
207
593
284
282
283
⑤
New Zealand
Chatham Rise
594

Figure 1. Physiographic diagram of the Leg 90 area showing 1000-fathom contour, adapted from Mammerickx, et al. (1971). Major water mass boundaries are illustrated as follows: 1, Equatorial Divergence; 2, Southern Tropical Divergence; 3, Southern Tropical Convergence; 4, Subtropical Divergence; 5, Subtropical Convergence; squares around sites represent areas of detailed bathymetry illustrated in individual site reports.

boundaries that occur in the region and separate the distinctive surface water masses shown in Figure 1. The sites were located so as to provide stratigraphic sections within each of the water masses, with Site 586 being in the tropical waters, Site 587 at the edge of the warm subtropics, Site 588 within the warm subtropics, Sites 589, 590, and 591 on the subtropical divergence in a transitional region located between warm subtropical and temperate areas, Sites 592 and 593 within temperate waters, and Site 594 in northern subantarctic waters immediately south of the subtropical convergence. All sites were located at water depths of between 1000 and 2200 m in areas that show simple pelagic sequences of calcareous sediments.

Previous rotary drilling in the region during DSDP Legs 21 and 29 demonstrated that the southwest Pacific is optimal for the study of relatively uncomplicated and continuously deposited carbonate sequences of Neogene

Table 1. Leg 90 coring summary.

Hole	Dates (1982/83)	Latitude	Longitude	Water Depth[a]	Penetration	No. of cores	Meters cored	Meters recovered	Percentage recovered
587	Dec. 3–5	21°11.87′S	161°19.99′E	1101 m	147.0	17	147.0	88.81	60.4
588	Dec. 6–7	26°06.7′	161°13.6′	1533	245.7	26	236.00	220.76	93.5
588A	Dec. 8	26°06.7′	161°13.6′	1533	344.4	18	108.40	84.27	77.7
588B	Dec. 8–10	26°06.7′	161°13.6′	1533	277.4	31	277.4	255.87	92.2
588C	Dec. 10–11	26°06.7′	161°13.6′	1533	488.1	19	182.4	134.61	73.8
589	Dec. 12–13	30°42.72′	163°38.39′	1391	36.1	4	36.1	35.08	97.2
590	Dec. 15	31°10.02′	163°21.51′	1299	26.2	3	26.2	26.36	100
590A	Dec. 15–17	31°10.02′	163°21.51′	1299	280.8	27	254.6	224.17	88
590B	Dec. 17–19	31°10.02′	163°21.51′	1299	499.1	53	499.1	465.26	93.2
591	Dec. 19–20	31°35.06′	164°26.92′	2131	283.1	31	283.1	278.21	98.3
591A	Dec. 20–22	31°35.06′	164°26.92′	2131	284.6	30	284.60	233.15	81.9
591B	Dec. 23–24	31°35.06′	164°26.92′	2131	500.4	24	229.80	130.86	56.9
592	Dec. 25–27	36°28.40′	165°26.53′	1098	388.5	41	388.5	340.12	87.5
593	Dec. 28–30	40°30.47′	167°40.47′	1068	571.5	60	571.50	468.21	81.9
593A	Dec. 30–Jan. 1	40°30.47′	167°40.47′	1068	496.8	27	257.30	227.71	88.5
594	Jan. 3	45°31.41′	174°56.88′	1204	505.1	53	505.1	299.72	59.3
594A	Jan. 6–7	45°31.41′	174°56.88′	1204	639.5	26	249.6	161.55	64.7
594B	Jan. 7–7	45°31.41′	174°56.88′	1204	42.9	5	42.9	34.18	79.6

[a] Water depth at sea level.

age between the equator and the subantarctic region. Unlike nearly all other oceanic regions, shallow-water platforms extend latitudinally over vast distances, providing an opportunity for drilling into oceanic pelagic sequences at shallow depths. These include Ontong-Java Plateau (Site 586) at the equator, Lord Howe Rise (Sites 587 through 592), the Challenger Plateau west of New Zealand (Site 593), and Chatham Rise east of New Zealand (Site 594).

The Lord Howe Rise is one of the major submarine topographic features of the southwest Pacific, extending northward from central western New Zealand to its northern limits at Lansdowne Bank at about 20°S. The rise is about 2000 km long and 300 km wide and its crest generally lies at water depths ranging from 750 to 1200 m deep. This rise is bounded to the west by the Lord Howe and Tasman basins and to the east by New Caledonia Basin. According to Burns, Andrews, et al.(1973), Jongsma and Mutter (1978), and Wilcox et al. (1980), the crustal structure of the rise is continental in origin, with the eastern flank probably representing the ancient (pre-Maestrichtian) continental margin of the "Australian-Antarctic Supercontinent." The known geologic record began in the Late Cretaceous (96 Ma) with the eruption of rhyolites possibly at or near sea level (McDougall and van der Lingen, 1974). During the Maestrichtian, silty claystone (drilled at Site 207) was deposited in a shallow marine environment in the southern part of the rise. This was followed by subsidence to approximately present-day upper bathyal depths in the early Eocene. In the northern part of the rise, oceanic biogenic sedimentation had commenced by the late Cretaceous, when the rise reached upper bathyal depths.

The paleoceanographic importance of Lord Howe Rise is that it provides an extremely long north–south-trending shallow-water pedestal upon which lie pelagic sequences of Cenozoic age. Neogene sediments on the rise are carbonate oozes deposited above the foraminiferal lysocline, and hence, they contain calcareous assemblages of excellent preservational character. Since the rise is surrounded by basins in an oceanic setting, there is little terrigenous sedimentary dilution in the Cenozoic section. The previous drilling showed that the Neogene and late Paleogene sequence contains very few hiatuses. This can be compared with the Paleogene, which is much dissected by several hiatuses, including the major regional unconformity associated with the Eocene/Oligocene boundary (Kennett et al., 1972; Burns, Andrews, et al., 1973). The Neogene sequences that lie on the Lord Howe Rise are therefore ideal for paleoceanographic investigations over a wide latitudinal range.

During the Neogene the sites on the Lord Howe Rise have experienced about 5 to 10° of northerly movement, in association with movement of the Indian Plate (J. Sclater and L. Meinke, pers. comm., 1983). This northward movement from higher to lower latitudes must have had an important effect upon the paleobiogeography of the planktonic microfossil assemblages.

In addition to the latitudinal traverse designed largely to study the history of surface-water paleoceanographic change and related sediment history, the Lord Howe Rise also offers a good opportunity to drill a traverse of sites at different water depths for paleoceanographic studies within the vertical water column. Three closely adjacent sites now provide such a traverse. These are Site 590 at 1299 m, Site 591 at 2131 m, and Site 206 at 3196 m. These three sites, in combination, will provide the opportunity to carry out detailed studies of changes in the intermediate water masses between 1000 and 3000 m water depths.

Three previously drilled sites were reoccupied to provide much higher quality Cenozoic sequences (Sites 289, 208, and 284) and a new site close to Site 207 was also drilled.

Scientific investigations planned for Leg 90 materials include the following:

1. High-resolution Neogene biostratigraphy.
2. Latest Paleogene through Neogene paleoclimatic history and surface-water fluctuations in the region using stable isotopes and microfossils.

3. Cross-latitudinal biostratigraphic correlations between sites.

4. Paleobiogeographic change of planktonic foraminifera and other microfossils in relation to paleoceanographic fluctuations and to the northward movement of the Lord Howe Rise during the Neogene.

5. Magnetostratigraphy of the cored sequences to enhance correlation and provide a geochronology.

6. Evolutionary studies of planktonic foraminifera to assist in evaluating different possible processes of evolution, such as punctuated equilibrium versus gradualism.

7. Benthic foraminiferal assemblage changes at these relatively shallow depths during the late Paleogene and Neogene to study paleobiogeography, taxonomic evolution, and the history of vertical water mass changes at intermediate depths in the southwest Pacific.

8. Stable isotopic studies of vertical water mass structure.

9. History of eolian sedimentation related to the development of Australian dry climates and deserts. Leg 21 scientists discovered a minor wind-blown quartz fraction in sediments younger than the middle Miocene of Site 208 and inferred that it was derived from Australia. Quantitative studies will be carried out and compared with paleoclimatic data.

10. Physical properties of sediments, including relations with seismic data.

11. Tephrochronology using volcanic ash layers.

TECHNIQUES

Hydraulic Piston Corer (HPC) and Variable Length Hydraulic Piston Corer (VLHPC)

In December of 1978, after a development period of approximately seven months, the Deep Sea Drilling Project deployed the first hydraulically actuated wire line piston corer (HPC). This coring system utilizes a hydraulic piston principle (Fig. 2). Fluid is pumped through the drill pipe, activating a piston-driven core barrel which, on failure of the shear pins, is ejected through the core bit into the sediment at the rate of approximately 20 ft./s. This extremely high penetration rate is used to decouple the core barrel from the motion of the drill string. On completion of each coring operation, the core barrel assembly is retrieved by wire line as in a conventional coring operation. The core bit is then "washed" down to the next coring point, where the piston coring procedure is repeated.

The VLHPC is an improved coring system which came into operation in May 1981. The VLHPC is able to recover cores up to 9.5 m in length in a standard butyrate liner. The core bit used is a special 11.5-in. outside diameter (O.D.) roller cone bit with a 3.62-in. core throat. Coring is discontinued when the sediments become too indurated, a condition characterized by incomplete penetration of the core barrel. When this occurs, the newly developed extended core barrel (XCB) is utilized.

Extended Core Barrel

The XCB (Fig. 3) was developed in response to a long-recognized need to recover undisturbed cores in the intermediate zone where the sediment is too hard to be piston cored yet still too soft to be recovered effectively by means of standard rotary coring. It is designed to continue in the same hole after the VLHPC becomes ineffective. Rotating with the drill string, the XCB employs a cutting shoe studded with Stratapax (artificial diamond) cutting discs which extends 6 in. below the drill bit and which is lubricated by relatively low energy water jets. This allows the XCB to core soft sediments before they can be washed away by the more energetic drill bit jets. Harder sediments will cause the barrel to retract into the drill bit against the pressure of an internal spring, allowing indurated sediments to be cut predominantly by the roller cones and strong water jets of the drill bit.

The XCB uses the same bit as the VLHPC, allowing both tools to be run interchangeably in the same bottom-hole assembly. The bit has a 3.6 in. core throat to allow the core barrel to pass through, although a 2-5/16 in. diameter core is cut rather than the standard VLHPC 2-1/2 in. diameter core. The XCB also uses the same butyrate core liner as the standard and VLHPC coring systems; the liner and core catchers are set on bearings which decouple them from core barrel rotation.

Physical Properties

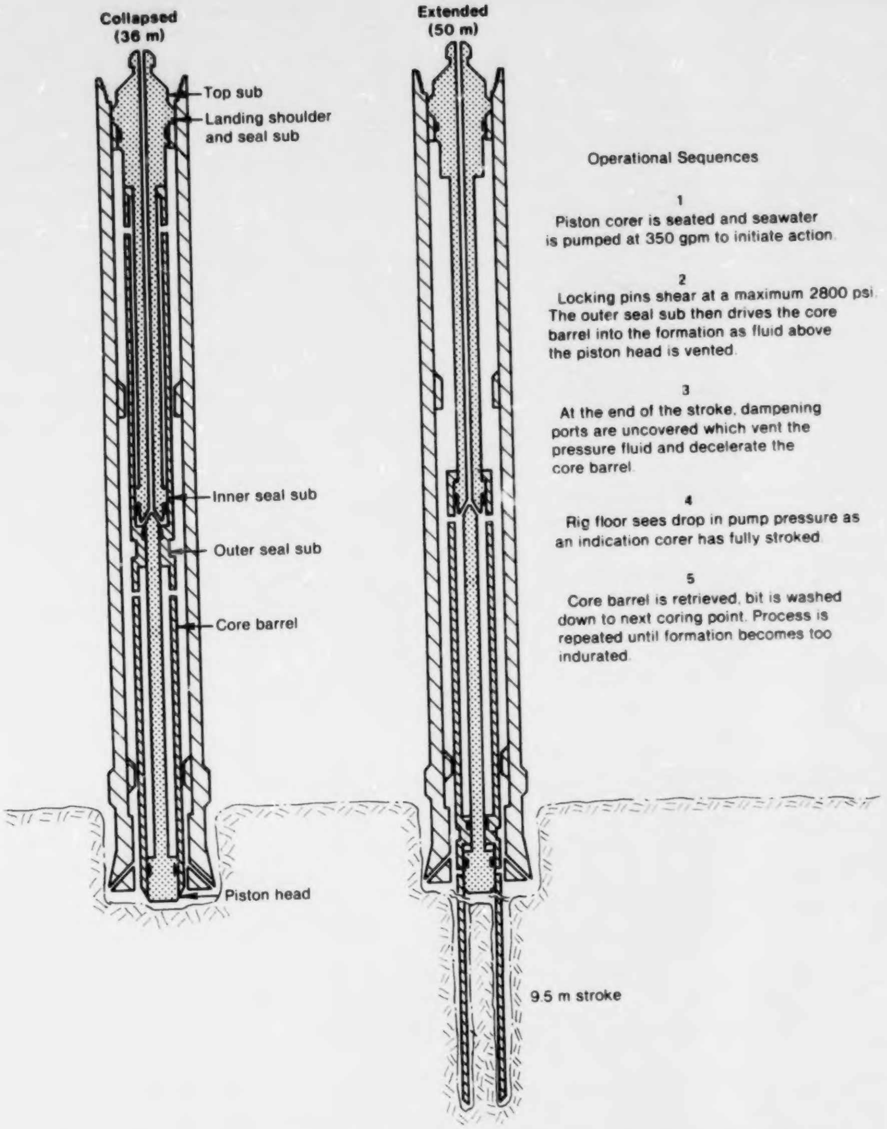
Laboratory equipment and measurement techniques utilized in the physical properties program are described in the following section. Not all of the properties listed below were measured for each core nor even in each hole. At sites with planned double HPC retrieval, many of the measurements were divided between the holes. The following physical properties were measured on the ship and are listed in the order in which they were made:

1. Saturated bulk density (with GRAPE)
2. Thermal conductivity (by needle probe method)
3. Acoustic velocity (with velocimeter)
4. Shear strength (with vane shear device)
5. Saturated bulk density, porosity, and grain density (by gravimetric techniques)
6. Carbonate content (by carbonate bomb technique).

GRAPE Saturated Bulk Density

Before the HPC cores were split, the 1.5 m-long sections were passed through the Gamma Ray Attenuation Porosity Evaluator (GRAPE). The geologic material travels between a shielded gamma-ray source and a shielded scintillation detector. The beam attenuation is directly related to the material's saturated bulk density, defined as weight per unit volume, and is expressed in units of g/cm^3. The instrument was developed by Evans (1965) and produces a continuous analog record of downhole density variations. Its shipboard application by DSDP is presented by Boyce (1976).

The accuracy of the GRAPE density values depends strongly upon the degree to which the core material fills the liner, since voids or breaks in the sediment-rock sequence affect the theoretical gamma-ray path length. Bennett and Keller (1973) reported erratic results in their GRAPE density measurements. The HPC, however, provides good-quality cores which completely fill the liner,



Operational Sequences

1

Piston corer is seated and seawater is pumped at 350 gpm to initiate action.

2

Locking pins shear at a maximum 2800 psi. The outer seal sub then drives the core barrel into the formation as fluid above the piston head is vented.

3

At the end of the stroke, dampening ports are uncovered which vent the pressure fluid and decelerate the core barrel.

4

Rig floor sees drop in pump pressure as an indication corer has fully stroked.

5

Core barrel is retrieved, bit is washed down to next coring point. Process is repeated until formation becomes too indurated.

Figure 2. Hydraulic piston corer, illustrating prefiring (collapsed) and postfiring (extended) positions.

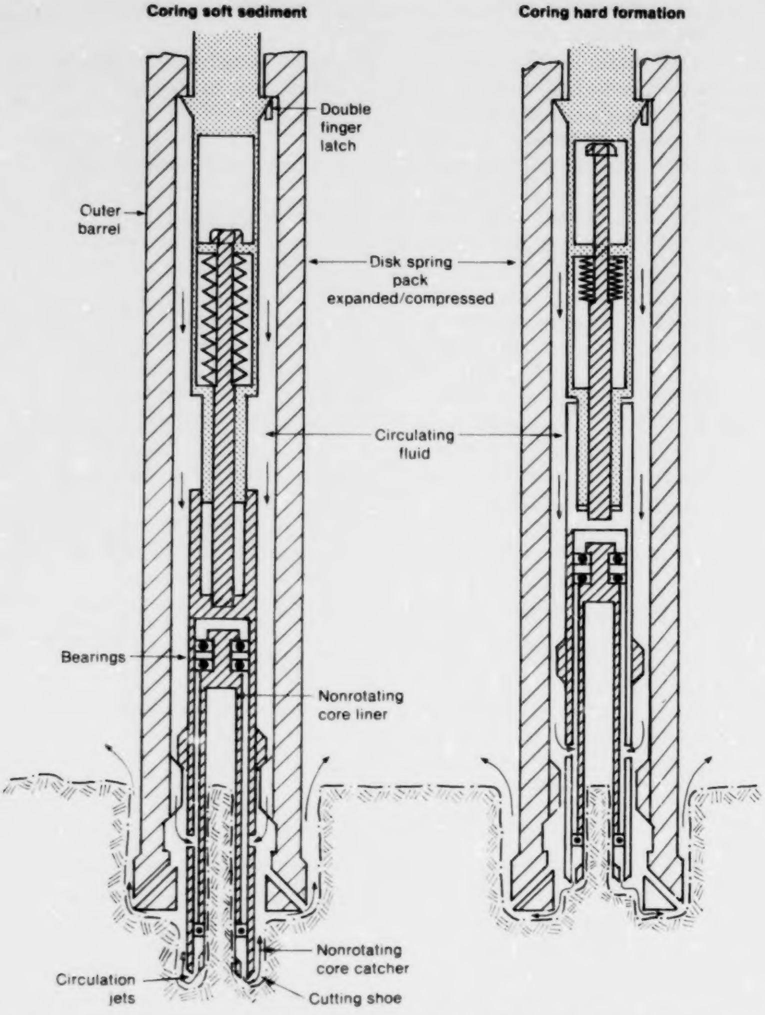
and Mayer (1982) found a very good correlation between the GRAPE-derived values and those determined in shore-based laboratories.

Thermal Conductivity

After the HPC cores had been exposed to the GRAPE device, sediment thermal conductivity was measured on the still unsplit cores. Holes (1/16 in. diameter) were drilled through the plastic liner and thermal conductivity probes were inserted through the liner and into the sediment. The Woods Hole Oceanographic Institution S-probe instrument and recorder were used in this particular case. Each probe contains a specified thermistor and a resistance wire which serves as a line heat source. Sediment temperature was measured with these needles, but further testing did not proceed until the cores reached thermal equilibrium within a maximum allowable drift. Thermal conductivity was subsequently determined by the needle probe method (Von Herzen and Maxwell, 1959), where the rise in temperature with time is logarithmically proportional to the conductivity. Temperature and pressure corrections necessary to estimate values at *in situ* conditions were applied (Morin and Silva, 1984). These were quite small, however, because of the generally shallow water depths.

Sonic Velocity

After the thermal conductivity had been measured, the cores were split and the speed of a compressional acoustic wave through the sediment was determined parallel to bedding. Measurements were made with the Hamilton Frame Velocimeter, utilizing 400 kHz P-wave trans-



Coring soft sediment

Coring hard formation

Figure 3. Extended core barrel, illustrating operation in both soft and hard formations.

ducers. One transducer was set directly on the sediment, the other was in contact with the core liner, and corrections for the liner material were applied to each measurement. Experimental theory and procedure are described by Boyce (1973). The technique is accurate to within ±2%.

Shear Strength

Immediately after the acoustic velocity was determined, the sediment shear strength was measured using a modified Wykeham Farrance miniature vane device. The vane was inserted into the sediment with its axis perpendicular to the core axis (parallel to bedding). Areas of obvious sediment disturbance were avoided when conducting this test. The vane rotates at a rate of 89°/min. and the maximum torque at time of failure is recorded. This value is combined with the appropriate spring constant and vane size parameters in order to arrive at a sediment shear strength. The laboratory device and its theory of operation are described in detail by Boyce (1977).

Gravimetric Techniques

In most cases, gravimetric data were collected by filling metal cylinders of known weight and volume with soft sediment from the split cores and immediately weighing them on a Cent-O-Gram balance. The ring weights were subtracted from these latter weights and, with the volume known, values of wet-bulk density were determined. When the sediments proved to be too lithified to accept the rings, solid chunks were taken from the cores. These were weighed in and out of water in order to determine their volumes.

The samples were then dried for 24 hr. at 110°C and allowed to cool in a desiccator for approximately 2 hr. before being weighed again. The volume of pore space can thus be evaluated by dividing the difference between the wet and dry weights by the density of the pore fluid, seawater. Porosity, which is defined as the volume of voids divided by the total volume, can subsequently be determined. Grain density is defined as the weight of the solid constituent divided by the volume of the solids, and is expressed in g/cm^3. This property was calculated from the porosity and wet-bulk density values. Results proved to be very erratic, probably because the metal cylinders were not filled precisely to the calibrated volume. Most of the sediments retrieved consisted of very high percentages of $CaCO_3$ and, in most cases, a sample grain density near that of $CaCO_3$ could be used as a rough approximating value.

Calcium Carbonate Content

Calcium carbonate content was determined on the ship for selected samples by the carbonate bomb technique. A specimen is initially powdered and treated with HCl in a sealed container. The resulting CO_2 gas and corresponding CO_2 pressure are proportional to the $CaCO_3$ content of the sediment sample. The method is described in detail by Müller and Gastner (1971).

Paleomagnetism

Intensities of magnetization of much of the sediment recovered were extremely low (<0.05 μG) at every site and could only be measured using a cryogenic magnetometer. Directional scatter in the results was correspondingly high and the quality of the paleomagnetic record gradually deteriorated as a function of depth. It was possible to obtain a magnetic polarity stratigraphy back to approximately 3 Ma at most sites (Fig. 4), but earlier than this only a few isolated polarity intervals could be identified.

Results described in the site reports that follow are based on NRM data only and are preliminary. Shipboard long-core measurements of the horizontal component of NRM were made on most cores from Hole 586B and Sites 587 and 588, but were abandoned when it became apparent that the sediments were too weakly magnetized to give reproducible results. As a rule most cores recovered with the HPC and XCB were subsampled at 50- and 75-cm intervals respectively. Only the more strongly magnetized specimens at each site were measurable on the shipboard Digico magnetometer. Virtually all NRM measurements reported here were preformed on the three-axis cryogenic magnetometer at the University of Rhode Island, which had a background noise level of typically 0.004 μG. Specimens were measured in two different positions relative to the sample holder, thus eliminating the effect of the magnetic moment of the holder along the vertical and one horizontal axis. The effect of the moment of the holder along the third axis was not eliminated, but would not affect the sign of the inclination, which was used predominantly for determining polarities. Data were discarded if the angle between the magnetic vector determined for the two positions exceeded 45°. Likewise, for determining polarities, data with intensities less than 0.008 μG were

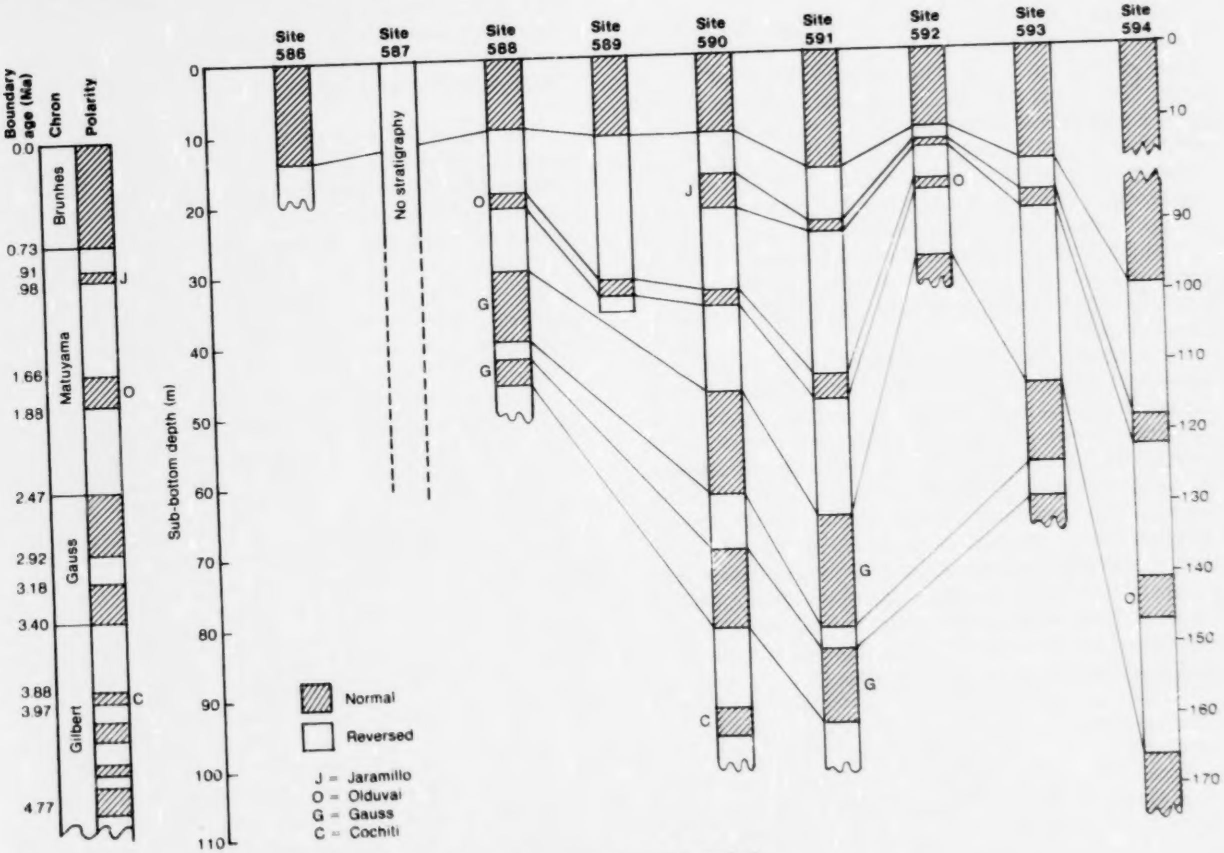


Figure 4. Magnetostratigraphy composite; column on left shows ages of epoch boundaries.

discarded. Despite these very loose criteria, typically 10% of the data were rejected because of the extremely low intensities of magnetization (often less than 0.01 μG) which were characteristic of most of the sediments studied.

Although the Kuster orientation tool performed well on occasions, absolute orientation data were obtained for considerably fewer than 50% of the HPC cores recovered.

Low-field magnetic susceptibility measurements were made on a modified Digico bulk susceptibility bridge with a noise level of about 0.08 μG/Oe. Much of the material measured was diamagnetic (negative susceptibility), but since magnetic susceptibility is a bulk property of the sediment it does not preclude a stable magnetic remanence which may be carried by only a small fraction of the magnetic grains.

A prominent high-intensity zone (about 1 to 10 μG) in the top few meters of nearly every section coincided with a pale brown, oxidized, surficial layer. Intensities dropped gradually to low values in the white-gray anoxic sediments beneath. As blebs and streaks of pyrite were common and in the latter, it is probable that a two-stage reduction of sulfates and iron oxides is occurring as described by Karlin and Levi (1983). The low intensities observed would be a consequence of this reduction process, together with dilution of the magnetic mineral input by very high carbonate contents (often 95 to almost 100%).

At Sites 588, 592, and 593, a uniform region of enhanced intensity (about 0.5 to 1μG) occurred within the latter part of the lower Miocene and the middle Miocene. The upper part of this region usually coincided with a pale yellow coloration of the sediments. Prominent high-intensity spikes (about 10 times neighboring values) were common in most sections, but did not correlate with any obvious macroscopic change in the sediments. These spikes could mark the remnants of altered ash layers. Measurements made on a number of the thin green-colored layers which were common did not indicate any of the intensity increase that would be expected in ash layers.

A comparison of shipboard NRM measurements with laboratory measurements made after storing specimens for six months showed a two- to threefold loss of intensity, most of which occurred during the first 36 hr. of storage. This was despite careful precautions to prevent the specimens drying out. Some loss of intensity during storage of wet sediments is common, though not usually so pronounced as noted here. It is difficult to believe that a small change in water content could produce such a large effect. Other possible causes are randomization of the alignment of small interstitial magnetic grains, and alteration of magnetic minerals which are unstable in the oxidizing storage environment.

Despite the high scatter in directions characteristic of these very weakly magnetized sediments, the NRM signal appears to be quite stable. Partial AF demagnetization tests were performed on a few of the more strongly magnetized specimens. Median destructive fields were typically in the range 125 to 300 Oe (12.5 to 30 mT). Directions generally remained stable up to fields of about 400 Oe (40 mT), beyond which most specimens were too weak to measure. Duplicate measurements indicated that the intensity threshold for obtaining repeatable polarities was about 0.008 μG. Scatter mean inclinations for most of the long sequences measured were in the range $-5°$ to $-13°$. This negative bias indicates the presence of a small normal-polarity overprint that is not sufficient to mask a primary reversal stratigraphy. A preponderance of intermediate and near-zero inclinations in a few zones suggests that long-term remagnetization can occur. However, this was not very common.

It was noticeable that the scatter in declinations was much greater than for the corresponding inclinations. Although the cause of this is unclear it suggests that cores become severely twisted within the core liners during coring, handling, and slicing. For this reason polarity interpretations have been based almost entirely on inclination data.

EXPLANATORY NOTES

Numbering of Sites, Holes, Cores, Samples

Drill site numbers run consecutively from the first site drilled by *Glomar Challenger* in 1968; thus each site number is unique. A site refers to the hole, or holes, drilled while using one acoustic positioning beacon. Several holes may be drilled at a single locality by pulling the drill string above the seafloor ("mud line") and offsetting the ship some distance (usually 100 m or more) from the previous hole. This sometimes becomes necessary where there is insufficient soft sediment at the last location to "spud in" or bury the bottom-hole assembly.

The first (or only) hole drilled at a site takes the site number. Additional holes at the same site are further distinguished by a letter suffix. The first hole has only the site number; the second has the site number with suffix "A"; the third has the site number with suffix "B"; and so forth. It is important for sampling purposes to distinguish the holes drilled at a site, since recovered sediments or rocks usually do not come from equivalent positions in the stratigraphic column at different holes.

Cores are numbered sequentially from the top down. In the ideal case, they consist of 9 m of sediment or rock in a cylindrical plastic liner. In addition, a short sample is obtained from the core catcher (a multifingered device at the bottom of the core barrel which prevents cored materials from sliding out during core-barrel recovery). This usually amounts to about 20 cm of sediment and is stored separately. This sample, from each core, represents the lowest stratum recovered in the particular cored interval. The core-catcher sample is designated by CC (e.g., 590A-6,CC is the core-catcher sample of the sixth core taken in the second hole drilled at Site 590).

The cored interval is the interval in meters below the seafloor measured from the point at which coring for a particular core was started to the point at which it was terminated. This interval is generally 9.5 m (nominal length of a core barrel) but may be shorter if conditions dictate. Cores and cored intervals need not be contiguous. In soft sediment, the drill string can be "washed ahead" without recovering core by applying sufficiently high pump pressure to wash sediment out of the way of the bit. In a similar manner, a center bit, which fills the opening in the bit face, can replace the core barrel if drilling ahead without coring is necessary.

When a core is brought aboard *Glomar Challenger*, it is labeled and the plastic liner and core cut into 1.5-m sections. A full 9-m core would thus consist of six sections, numbered from the top down as 1 to 6. (The discrepancy between the 9.0-m core and 9.5-m core is discussed below.) Generally, somewhat less than 9 m is recovered. In this case, the sections are still numbered starting with 1 at the top, but the number of sections is the number of 1.5-m intervals needed to accommodate the length of core recovered; this is illustrated in Figure 5.

Thus, as shown, recovery of 3.6 m of sediment would result in a core with three sections, with a void of 0.9 m at the top of the first section. By convention, and for convenience in routine data handling at the Deep Sea Drilling Project, if a core contains a length of material less than the length of the cored interval, the sections of that recovered material are arbitrarily placed at the top of the cored interval, with the top of Section 1 (not always the top of the sediment) located at the top of the cored interval.

It was noted above that a discrepancy exists between the usual coring interval of 9.5 m and 9-m length of core recovered. The core liners used are actually 9.28 m in length, and the core catcher accounts for another 0.2 m. In cases where the core liner is recovered full to the top, the core is still cut into 1.5-m sections, measured from the top of the liner.

Samples taken from core sections are designated by the interval in centimeters from the top of the core section from which the sample was extracted; the sample size in cc (cm^3), is also given. Thus, a full sample designation would consist of the following information:

Leg
Site (hole , if other than first hole)
Core number
Section number
Interval in centimeters from top of section
Volume.

Sample 590A-1-3, 122–124 cm (10 cc) designates a 10-cm^3 sample taken from Section 3 of Core 1 from the second hole drilled at Site 590. The depth below the seafloor for this sample would then be the depth to the top of the cored interval plus 3 m for Sections 1 and 2, plus 122 cm, which represents the depth below the top of Section 3.

Lithologic Classification

The basic lithological classification used to name a sediment type in this volume is a modified version of the system devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties. We modified the basic classification to describe only the facies we recovered. The classification is descriptive, no genetic implication is intended, and the divisions between sediment types are often artificial. The assignment of a name was based on properties that were estimated aboard ship.

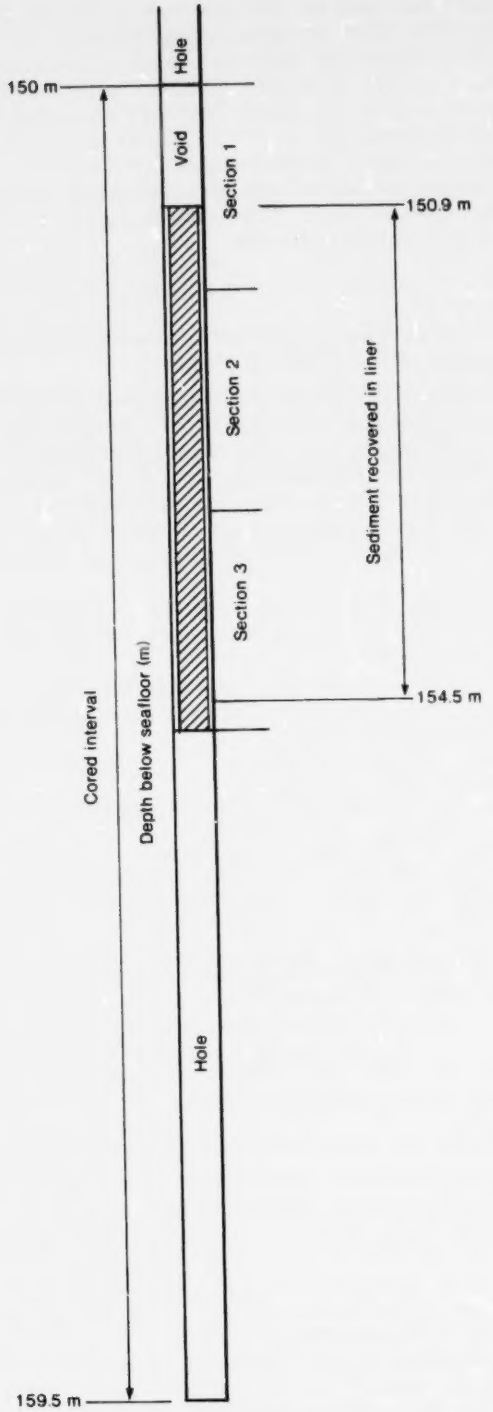


Figure 5. Position of incomplete sediment recovery within the cored interval.

Names of sediments are defined only on the basis of a qualitative estimate of composition and texture from a microscopic examination of smear slides. Colors were matched with the Geological Society of America Rock-

Color Chart, and the full color code is recorded on the core forms at the end of each site chapter.

Four classes were used for firmness. *Soft* is used to denote an ooze with little strength that is readily deformed by spatula or finger. The term *firm* is used to describe sediment that is stiff and resists deformation by spatula or finger. The terms *chalk* and *limestone* denote calcareous sediments with the consistency of blackboard chalk or harder. The sediment classification used on Leg 90 is outlined below.

Classification and Nomenclature Rules

1. Rules for Class Limits and Sequential Listing of Constituents in a Sediment Name

A. Major Constituents: Sediment assumes names of those constituents present in major amounts (major is defined as greater than 25%). Where more than one major constituent is present, the one in greatest abundance is listed farthest to the right. The remaining major constituents are listed progressively farther to the left in order of decreasing abundance. (See second example in Rule 1B.)

B. Minor Constituents: Constituents present in the amounts of 5–25% are prefixed to the sediment name by the term *bearing*.

The following example illustrates sediment names for various percentages of foraminifers and nannofossils in a two-component sediment.

Foraminifers	Nannofossils	Description
0–5	95–100	Nannofossil ooze
5–25	75–95	Foraminifer-bearing nannofossil ooze
75–95	5–25	Nannofossil-bearing foraminifer ooze
95–100	0–5	Foraminifer ooze

A three-component sediment with a composition of 50% nannofossils, 30% foraminifers, and 20% diatoms would be called a diatom-bearing foraminifer nannofossil ooze. An example of one containing terrigenous components, say 10% silt, 30% clay, and 60% nannofossils is a silt-bearing clayey nannofossil ooze.

2. Specific Rules for Calcareous and Siliceous Tests

A. *Nannofossil* is applied only to the calcareous tests of coccolithophorids, discoasters, and the like.

B. The terms *calcareous* and *siliceous*, depending on skeletal composition, are applied where no attempt was made to distinguish fossils as to major subgroup. Thus if no estimate is made, a mixture of radiolarians, diatoms, and silicoflagellates would be called a siliceous ooze. Where the distinction is made, the appropriate fossil name is used.

C. Fossil tests are not qualified by a textural term unless they have obviously been redeposited.

Determinations of Shipboard Mineralogy and Lithology

Smear Slides

Smear slides were the principal means of identifying sediment components on the ship. Component abundances in smear slides are based on a semiquantitative visual estimate, using the following classes:

<1%	Trace (T)
1–5%	Rare (R)
5–25%	Common (C)
25–75%	Abundant (A)
>75%	Dominant (D)

Many cores contain important minor lithologies as well as a dominant lithology. The description of the dominant lithology is indicated in all cases, and descriptive information for minor lithologies is included wherever possible. Quantities of terrigenous clay were difficult to determine from smear slides and are likely to have been underestimated in some cases. Major and minor abundances from each smear slide examined aboard ship are tabulated in the smear slide summary in each site chapter.

An example of a core form with legend and explanatory notes appears in Figure 6.

Sediment Color

Colors recorded in core summaries were determined during shipboard examination immediately after the core sections were split. Experience with carbonate sediment has shown that many of the colors will fade or disappear after opening and storage. Colors particularly susceptible to rapid fading are purple, light and medium tints of blue, light bluish gray, dark greenish black, light tints of green, and pale tints of orange. These colors change with time to white or yellowish white or pale tan.

Colors were often cyclic on a scale of 20 cm or less. This made identification of color boundaries on the core forms virtually impossible. Large-scale color variations are shown and, where possible, small fluctuations in color are indicated.

Coring Deformation

Four degrees of deformation were recognized and are noted by symbols on the sample core form (Fig. 6). Slightly deformed cores exhibit a slight bending of bedding contacts; extreme bending defines moderate deformation. In highly deformed cores, the original bedding may be completely disrupted so as to produce a "drilling breccia." Watery intervals generally have lost all original bedding characteristics and are described as "soupy."

Biostratigraphy

The zonal schemes and radiometric ages of key datum planes used during Leg 90 are shown in Figure 7.

Planktonic Foraminifers

Zones

Five sets of zonal schemes were used in the north-south traverse from the tropic to subantarctic waters.

Site 586 (= 289)	Tropical
Sites 588, 587	Warm subtropical
Sites 592, 590, 591	Cool subtropical
Site 593	Temperate
Site 594	Subantarctic

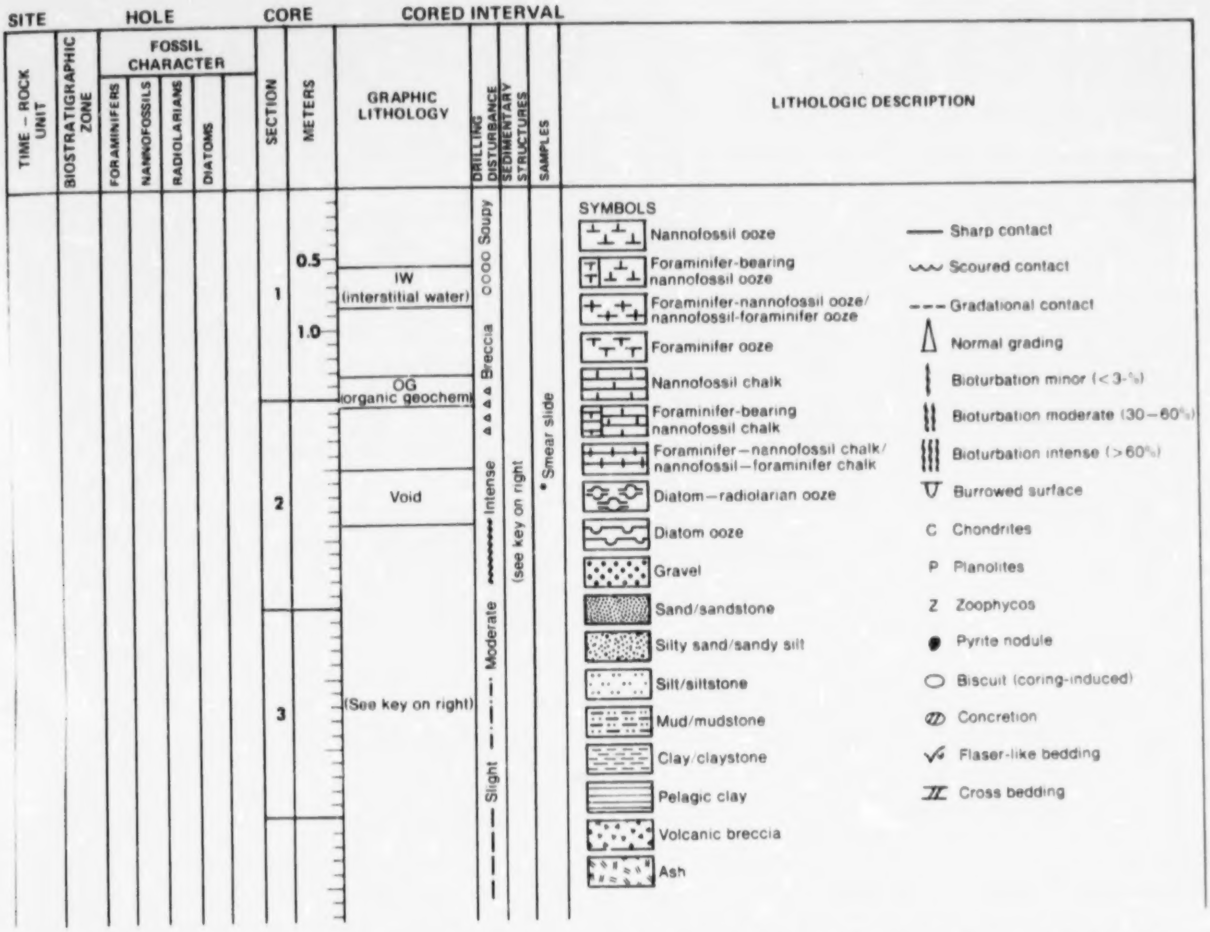

SITE
HOLE
CORE
CORED INTERVAL
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
IW (interstitial water)
OG (organic geochem)
Void
(See key on right)
Soupy
Breccia
Intense
Moderate
Slight
(see key on right)
• Smear slide
SYMBOLS
Nannofossil ooze
Foraminifer-bearing nannofossil ooze
Foraminifer-nannofossil ooze/ nannofossil-foraminifer ooze
Foraminifer ooze
Nannofossil chalk
Foraminifer-bearing nannofossil chalk
Foraminifer–nannofossil chalk/ nannofossil–foraminifer chalk
Diatom–radiolarian ooze
Diatom ooze
Gravel
Sand/sandstone
Silty sand/sandy silt
Silt/siltstone
Mud/mudstone
Clay/claystone
Pelagic clay
Volcanic breccia
Ash
Sharp contact
Scoured contact
Gradational contact
Normal grading
Bioturbation minor (<3-%)
Bioturbation moderate (30–60%)
Bioturbation intense (>60%)
Burrowed surface
C Chondrites
P Planolites
Z Zoophycos
Pyrite nodule
Biscuit (coring-induced)
Concretion
Flaser-like bedding
Cross bedding

Figure 6. Sample of core form with the various symbols and descriptive codes used in this volume. Note that the graphic lithology column is based solely on smear slide estimates.

Zonal Markers

The zonal boundaries are defined on the initial appearances extinctions of zone fossils.

Diachronic Nature of Some Zonal Boundaries

1. The *Globorotalia truncatulinoides* Zone was recognized at Sites 586 through 592 but at Sites 593 and 594 its cryptogenic (sudden, nonevolutionary) appearance was stratigraphically later because the *Globorotalia truncatulinoides* ancestor *G. tosaensis* was not present.

2. *Globorotalia inflata* Zone. The base of the zone in the upper Pliocene, based on the first appearance of the zone fossil, appears to be reliable at Sites 592 and 593 because forms displaying its evolution from its immediate ancestor *Globorotalia puncticulata* are also present. There is evidence based on diatoms that the appearance of *G. inflata* at Site 594 is stratigraphically late and occurs in the Pleistocene.

3. At Sites 587 and 588 the first appearances of *G. puncticulata* and *G. inflata* are probably stratigraphically late because they evolved farther south and later migrated northward.

Major Boundaries

The planktonic foraminifer and calcareous nannoplankton species used to identify major boundaries are shown in Figure 8. There are slight offsets regarding these boundaries depending on the fossil group used. This is discussed in Martini et al. (this volume). For general uniformity foraminifer-based boundaries were used in this volume except in the individual fossil chapters.

Calcareous Nannoplankton

The standard calcareous nannoplankton zonation (Martini, 1971) is used at all sites to identify nannoplankton zones. However, from Site 592 southward, zones based on *Discoaster, Ceratolithus, Catinaster*, and *Sphenolithus* species had to be combined because most of them do not occur in subantarctic waters. In these cases the zones are identified as NN13/NN12, NN19a/NN16, etc. Zones NN11 and NN19 can be subdivided into two subzones each with additional letters a or b behind the numbers (e.g., NN11a). For further details see Martini (this volume) and Lohman (this volume).

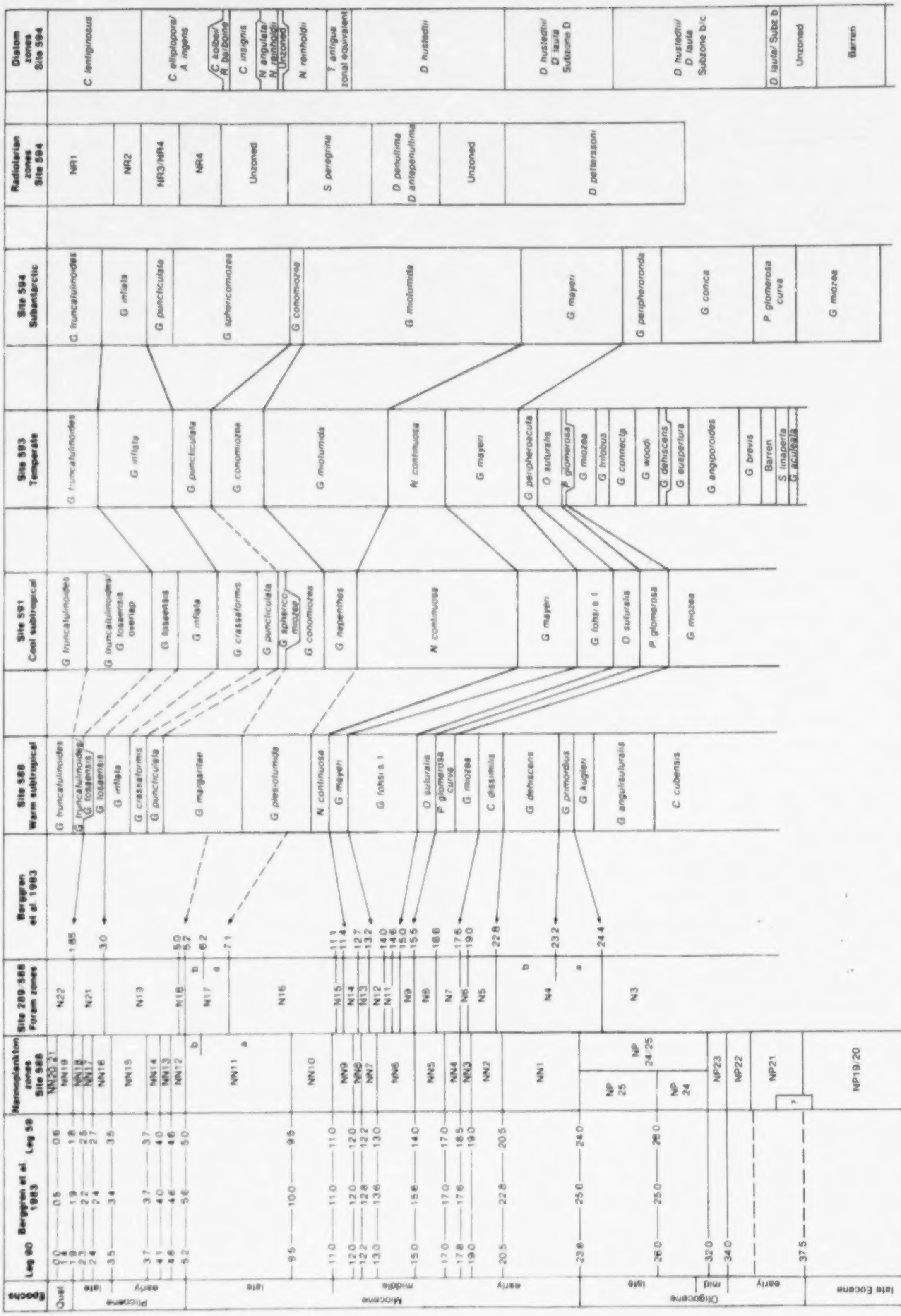


Figure 7. Leg 90 late Eocene–Quaternary planktonic zones and datums.

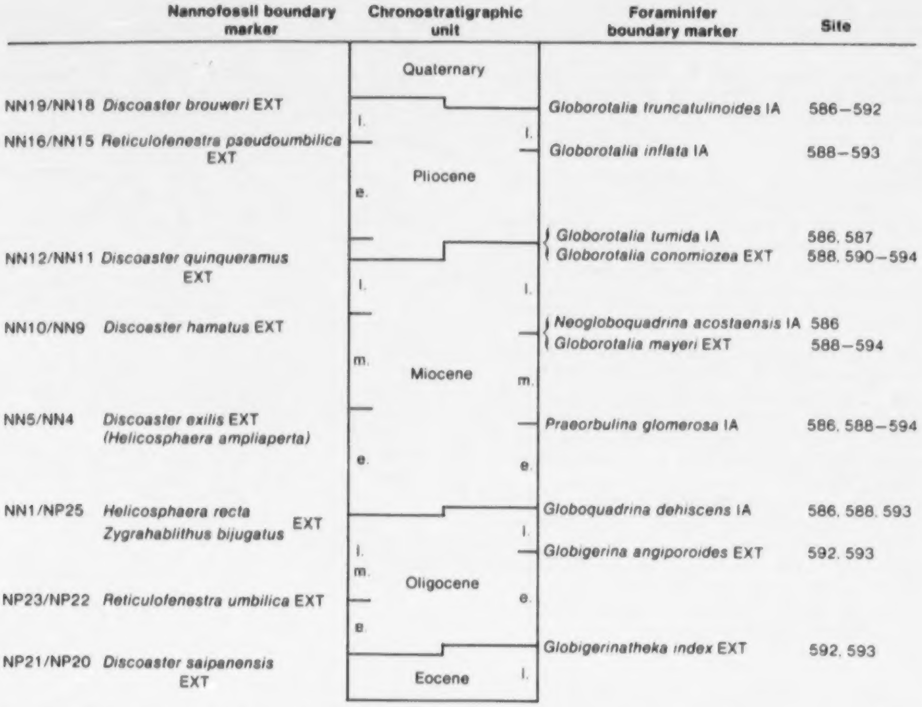

Nannofossil boundary marker
Chronostratigraphic unit
Foraminifer boundary marker
Site
Quaternary
NN19/NN18 Discoaster brouweri EXT
Globorotalia truncatulinoides IA 586–592
NN16/NN15 Reticulofenestra pseudoumbilica EXT
Globorotalia inflata IA 588–593
Pliocene
l.
e.
Globorotalia tumida IA 586, 587
Globorotalia conomiozea EXT 588, 590–594
NN12/NN11 Discoaster quinqueramus EXT
NN10/NN9 Discoaster hamatus EXT
Neogloboquadrina acostaensis IA 586
Globorotalia mayeri EXT 588–594
Miocene
m.
NN5/NN4 Discoaster exilis EXT (Helicosphaera ampliaperta)
Praeorbulina glomerosa IA 586, 588–594
NN1/NP25 Helicosphaera recta Zygrahablithus bijugatus EXT
Globoquadrina dehiscens IA 586, 588, 593
Globigerina angiporoides EXT 592, 593
Oligocene
NP23/NP22 Reticulofenestra umbilica EXT
NP21/NP20 Discoaster saipanensis EXT
Globigerinatheka index EXT 592, 593
Eocene

Figure 8. Nannofossils and planktonic foraminifers used to identify major boundaries. Ext = extinction; IA = initial appearance.

Silicoflagellates

The high northern latitude silicoflagellate zonation used during Leg 38 (Martini and Müller, 1976) is employed for zonation in the Neogene of Sites 591 and 594 and in the Eocene of Site 588.

Radiolarians and Diatoms

Radiolarian and diatom zonations were used at Site 594. The radiolarian zonation is a mixture of tropical and subantarctic zones (Riedel and Sanfilippo, 1977; Chen, 1975; Caulet, 1982), the diatom Antarctic/subantarctic zones are after Weaver and Gombos (1981) and Ciesielski (1983), and the mid-latitude zones of Barron (1980, 1981).

Abbreviations

HPC	Hydraulic piston corer
VLHPC	Variable-length hydraulic piston corer
XCB	Extended core barrel
BSF	Below seafloor
BHA	Bottom-hole assembly
DPM depth	Drill pipe measured depth
CC	Core catcher
PDR	Precision depth recorder
OG	Organic geochemistry
IW	Interstitial water
GRAPE	Gamma ray attenuation porosity evaluator
IA	Initial appearance (biostratigraphic context)
LA	Last appearance (biostratigraphic context)

The following abbreviations and units are used in the paleomagnetic reports:

NRM	Natural remanent magnetization
AF	Alternating field
MDF	Median destructive field
μG	10^{-6} gauss (= 1 $mA \cdot m^{-1}$), unit of intensity of magnetization, i.e., magnetic moment per unit volume.
Oe	oersted, unit of magnetic field strength. 10 Oe is equivalent to a magnetic flux density of 1 mT in a vacuum.
mT	10^{-3} tesla, SI unit of magnetic flux density (induction).
μG/Oe	cgs unit of volume susceptibility, equivalent to 4π SI units.

The magnetic polarity time scale used is that described by Berggren et al. (in press).

REFERENCES

Barron, J. A., 1980. Lower Miocene to Quaternary diatom biostratigraphy of Leg 57, off northeastern Japan, Deep Sea Drilling Project *In* Scientific Party, *Init. Repts. DSDP*, 56, 57, Pt. 2: Washington (U.S. Govt. Printing Office), 641-686.

________, 1981. Late Cenozoic diatom biostratigraphy and paleoceanography of the middle latitude eastern North Pacific, Deep Sea Drilling Project Leg 63. *In* Yeats, R. S., Haq, B. U., *Init. Repts. DSDP*, 63: Washington (U.S. Govt. Printing Office), 507-538.

Bennett, R. H., and Keller, G. H., 1973. Physical properties evaluation. *In* van Andel, Tj. H., Heath, G. R., et al., *Init. Repts. DSDP*, 16: Washington (U.S. Govt. Printing Office), 513-521.

Berggren, W. A., Kent, D. V., and Van Couvering, J. A., in press. Neogene chronology and chronostratigraphy. *Geol. Soc. London*.

Boyce, R. E., 1973. Appendix I. Physical property—methods. *In* Edgar, N. T., Saunders, J. B., et al., *Init. Repts. DSDP*, 15: Washington (U.S. Govt. Printing Office), 1115-1128.

________, 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931–958.

________, 1977. Deep Sea Drilling Project procedures for shear strength measurement of clayey sediment using modified Wykeham Farrance laboratory vane apparatus. *In* Barker, P. F., Dalziel, I. W. D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 1059–1068.

Burns, R. E., Andrews, J. E., et al., 1973. *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office).

Caulet, J. P., 1982. Faunes de radiolaires et fluctuations climatiques dans les sédiments de l'océan indien austral: une nouvelle biozonation. *Bull. Soc. Geol. France, Ser. 7*, 24:555–562.

Chen, P. -H., 1975. Antarctic radiolaria. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 437–513.

Ciesielski, P. F., 1983. The Neogene and Quaternary diatom biostratigraphy of subantarctic sediments, Deep Sea Drilling Project Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., *Init. Repts. DSDP*, 71, Pt. 2: Washington (U.S. Govt. Printing Office), 635–665.

Evans, H. B., 1965. GRAPE—A device for continuous determination of material density and porosity. *Trans. SPWIA Logging Symposium*, 6th Ann. Dallas, Tx., 2:B-1-B25.

Jongsma, D., and Mutter, J. C., 1978. Nonaxial breaching of a rift valley: Evidence from the Lord Howe Rise and the southeastern Australian Margin, *Earth Planet. Sci. Lett.*, 39:226–234.

Karlin, R., and Levi, S., 1983. Diagenesis of magnetic minerals in Recent hemipelagic sediments. *Nature*, 303:327–330.

Kennett, J. P., Burns, R. E., Andrews, J. E., Churkin, M., Davies, T. A., et al., 1972. Australia-Antarctic continental drift, paleocirculation changes and Oligocene deep-sea erosion. *Nature Phys. Sci.*, 239(91):51–55.

Knox, G. A., 1970. Biological oceanography of the South Pacific. *In* Wooster, W. S. (Ed.), *Scientific Exploration of the South Pacific:* Washington (National Academy of Science), pp. 155–182.

McDougall, I., and van der Lingen, G. J., 1974. Age of rhyolites of the Lord Howe Rise and the evolution of the southwest Pacific Ocean. *Earth Planet. Sci. Lett.*, 21:117–126.

Mammerickx, J., Chase, T. E., Smith, S. M., and Taylor, I. L., 1971. *Bathymetry of the South Pacific:* La Jolla (Scripps Institution of Oceanography).

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proc. II Planktonic Conf., Roma 1970* (Vol. 2): Rome (Edizioni Tecnoscienza), 739–785

Martini, E., and Müller, C., 1976. Eocene to Pleistocene silicoflagellates from the Norwegian-Greenland Sea (DSDP Leg 38). *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP*, 38: Washington (U.S. Govt. Printing Office), 857–895.

Mayer, L. A., 1982. Physical properties of sediment recovered on Deep Sea Drilling Project Leg 68 with the hydraulic piston corer. *In* Prell, W. L., Gardner, J. V., et al., *Init. Repts. DSDP*, 68: Washington (U.S. Govt. Printing Office), 365–382.

Morin, R., and Silva, A. J., 1984. Effects of high pressure–high temperature on some physical properties of ocean sediments. *J. Geophys. Res.*, 89:511–526.

Müller, G., and Gastner, M., 1971. The "Karbonat Bombe," a simple device for the determination of carbonate content in sediments, soils, and other materials. *N. Jahrb. Mineral. Monatsh.*, 10: 466–469.

Riedel, W. R., and Sanfilippo, A., 1977. Cenozoic Radiolaria. *In* Ramsay, A. T. S. (Ed.), *Oceanic Micropaleontology*: New York (Academic Press), pp. 847–912.

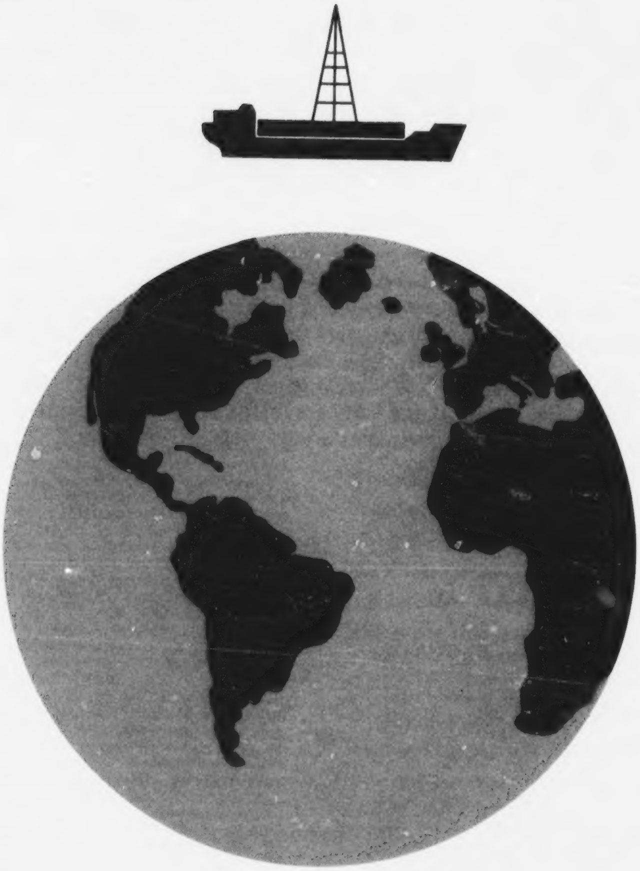
Von Herzen, R. P., and Maxwell, A. E., 1959. The measurement of thermal conductivity of deep-sea sediments by a needle-probe method. *J. Geophys. Res.*, 64:1557–1563.

Weaver, F. M., and Gombos, A. M., 1981. Southern high latitude diatom biostratigraphy. *In* Warme, T. E., Douglas, R. C., and Winterer, E. L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress*. Soc. Econ. Paleont. Mineral. Spec. Publ., 32:445–470.

Wilcox, J. B., Symonds, P. A., Hinz, K., and Bennett, D., 1980. Lord Howe Rise, Tasman Sea–preliminary geophysical results and petroleum prospects. *B.M.R. J. Aust. Geol. Geophys.*, 5:225–236.

Date of Acceptance: 12 December 1983

PART II: SITE REPORTS



The descriptions of sites, cores, and data included in these site reports were completed within one year of the cruise, but many of the topical chapters that follow were completed at a later date. More data were acquired and authors' interpretations matured during this interval, so readers may find some discrepancies between site reports and topical papers. The timely publication of the *Initial Reports* series, which is intended to report the early results of each leg, precludes incurring the delays that would allow the site reports to be revised at a later stage of production.

2. SITE 586: WESTERN EQUATORIAL PACIFIC[1]

Shipboard Scientific Parties of Legs 89 and 90[2]

HOLE 586

Date occupied: 19 November 1982

Date departed: 19 November 1982

Time on hole: 15 hr., 52 min.

Position: 00°29.84′S; 158°29.89′E

Water depth (sea level; corrected m, echo-sounding): 2208

Water depth (rig floor; corrected m, echo-sounding): 2218

Bottom felt (m, drill pipe): 2223.1. Note: water depth of 2218 m from rig floor from 586C logs used as site datum.

Penetration (m): 39.3

Number of cores: 5

Total length of cored section (m): 39.3

Total core recovered (m): 38.98

Core recovery (%): 99.2

Oldest sediment cored:
Depth sub-bottom (m): 39.3
Nature: Foraminifer-bearing nannofossil ooze
Age: Latest Pliocene
Measured velocity (km/s): Not measured

Basement: Not encountered

Principal results: This was to be the first of two overlapping sets of cores obtained by the hydraulic piston corer (HPC) on the edge of the Ontong-Java Plateau. While we were attempting to retract the barrel of Core 6, the barrel broke and was left outside the bit, forcing early abandonment of the hole.

HOLE 586A

Date occupied: 19 November 1982

Date departed: 20 November 1982

Time on hole: 1 day, 3 hr., 46 min.

Position: 00°29.84′S; 158°29.89′E

Water depth (sea level; corrected m, echo-sounding): 2208

Water depth (rig floor; corrected m, echo-sounding): 2218

Bottom felt (m, drill pipe): Not felt. Note: water depth of 2218 m from rig floor from 586C logs used as site datum.

Penetration (m): 305.3

Number of cores: 31

Total length of cored section (m): 260.9

Total core recovered (m): 257.03

Core recovery (%): 98.5

Oldest sediment cored:
Depth sub-bottom (m): 305.3
Nature: Nannofossil ooze and minor nannofossil chalk
Age: Earliest late Miocene
Measured velocity (km/s): 1.6

Basement: Not encountered

Principal results: Hole 586A was washed to the 39.3 m depth at which Hole 586 had to be abandoned. A Neogene section of foraminifer-bearing nannofossil ooze was recovered. With depth, foraminifer content decreases. Below 260 m the first thin chalk beds appear and foraminifers are few. Fossils examined from this site show a mixture of two components: whole specimens whose age increases with core depth, and broken and corroded specimens reworked and transported to the site.

HOLE 586B

Date occupied: 20 November 1982

Date departed: 22 November 1982

Time on hole: 1 day, 1 hr., 3 min.

Position: 00°29.84′S; 158°29.89′E

Water depth (sea level; corrected m, echo-sounding): 2208

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

[2] Holes 586, 586A, and 586C have been described by the Leg 89 shipboard scientific party, Hole 586B by the Leg 90 shipboard scientific party. Both are, therefore, listed here.

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Water depth (rig floor; corrected m, echo-sounding): 2218

Bottom felt (m, drill pipe): At or above 2219.4. Note: water depth of 2218 m from rig floor from 586C logs used as site datum.

Penetration (m): 240.3

Number of cores: 25

Total length of cored section (m): 240.3

Total core recovered (m): 234.93

Core recovery (%): 97.8

Oldest sediment cored:
Depth sub-bottom (m): 240.3
Nature: Foraminifer-bearing nannofossil ooze
Age: Late Miocene

Basement: Not encountered

Principal results: (by Leg 90 shipboard scientific party): This hole duplicated the upper 240 m at Site 586. It is a continuous, uncomplicated section from Quaternary to early late Miocene age, differing only in details from descriptions of Holes 586 and 586A. However, unlike the findings reported for Hole 586, there is little evidence of extensive reworking or turbidite layers. The hole terminated after an equipment failure (HPC piston) at 240.3 m.

HOLE 586C

Date occupied: 22 November 1982

Date departed: 23 November 1982

Time on hole: 1 day, 8 hr., 2 min.

Position: 00°29.84′S; 158°29.89′E

Water depth (sea level; corrected m, echo-sounding): 2208

Water depth (rig floor; corrected m, echo-sounding): 2218

Bottom felt (m, drill pipe): Not felt; 2218 m by gamma logs

Penetration (m): 623.1

Number of cores: 1

Total length of cored section (m): 9.6

Total core recovered (m): 2.18

Core recovery (%): 23

Oldest sediment cored:
Depth sub-bottom (m): 623.1
Nature: Nannofossil chalk and ooze
Age: early Miocene
Measured velocity (km/s): —

Basement: Not encountered

Principal results: Drilled to provide hole for logging thick section of carbonate ooze. Obtained suite of excellent logs.

BACKGROUND AND OBJECTIVES

The 1981–1983 *Glomar Challenger* drilling plan included three traverses designed to provide detailed information about Neogene paleoceanography and biostratigraphy through the recovery of sets of relatively complete and undisturbed cores of highly fossiliferous deep-sea sediment. The seafloor below areas of moderate to high productivity and above the carbonate compensation depth (CCD) allows calcareous foraminifers and nannofossils to accumulate and remain in a good state of preservation. Of the three traverses in areas of thick Neogene calcareous ooze, Leg 85 cored sites in the eastern equatorial Pacific, where cyclic productivity presumably controls cyclic sedimentation, and Leg 94 cored sites in the eastern North Atlantic to examine paleoceanographic changes across latitudinal belts.

A third series of sites extends across latitudinal oceanographic boundaries in the southwest Pacific. Broad areas of the seafloor elevated well above the CCD extend, with interruptions, from the Ontong-Java Plateau at the equator, past various rises between Melanesia and Australia, to the Bounty Trough, between Chatham Rise and Campbell Plateau, east of New Zealand. Boundaries of water masses may have shifted in response to changes in ocean circulation, owing to changing positions of land masses as the Australian lithospheric plate moved northward and the Melanesian island arcs evolved. Particular assemblages of fossil plankton characterize the various water masses between the equator and the Antarctic. Changes through time in the assemblages of ecologically dependent fossils at a drilling site are the records of past oceanographic changes there. The objective of Leg 90 was to use the HPC at several of these Neogene pelagic sites. JOIDES Planning Committee, however, assigned the northernmost site, SW-9, to Leg 89 to reduce the total amount of Leg 90 travel time.

SW-9 (Site 586) is the tropical end of the traverse. It lies on the northeastern upper slope of the Ontong-Java Plateau on a broad northeast-trending ridge between two swales that are the heads of submarine canyon systems. Although mass wasting at the plateau margins has been documented, and regional surveys suggest that a more complete section lies near the crest of the plateau 200 to 300 km to the southwest, Site 586 is located near existing DSDP Site 289 at 00°29.92′S, 158°30.69′E (Fig. 1). During Leg 30 that site was cored by a rotary bit continuously for 1262.5 m, with 56% average recovery, through Cenozoic and Cretaceous sediments into basaltic basement of Aptian or earlier age (Andrews, Packham, et al., 1975). The JOIDES Ocean Paleoenvironment Panel chose to schedule the HPC site at an existing continuously cored site in order to have a standard section that could be pieced together from the work of the two legs, rather than at spot-cored DSDP Site 64 (which

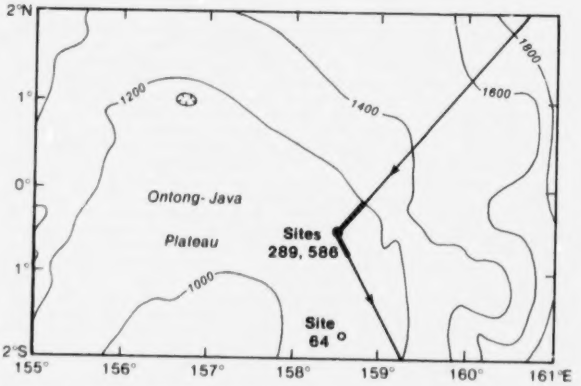

Figure 1. Regional bathymetry (fathoms) around Site 586, within one nautical mile of Site 289 on the northeast flank of the Ontong-Java Plateau. *Challenger* Leg 89 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2. Bathymetry after Mammerickx et al., 1974.

terminated in the Eocene) or at a new site that might not reach basement. Moreover, even though the Site 289 Neogene cores were disturbed and not complete in their recovery, so that HPC cores were needed for detailed work, they did not show any major discontinuities in the section above the lower Oligocene. The upper Oligocene and Miocene section is about 750 m thick at Site 289.

The principal aim at Site 586, therefore, was to obtain piston cores using the HPC to about 250 m depth or shallower, in the event that the resistance to shear by the sediment as it consolidated under burial increased to the degree that penetration died off significantly. Then, a second hole at the site was to be cored, offset slightly in distance and with the depth intervals of the second set of HPC cores adjusted so as to place the midpoints of the second set opposite the depths of the tops and bottoms of the first set. The pair of HPC holes, with overlapping cored intervals, was thereby expected to provide a continuous record: gaps in one set of cores should be filled by recovery in the other set. According to the Leg 30 paleontology report, 250 m depth would be within the upper Miocene, and it was expected that we would acquire a good record of late Neogene oceanographic events in the tropical belt of the western Pacific.

Of the lesser objectives for Site 586, the Leg 89 scientific party attempted as many as could be fitted into the time remaining for the leg. The cause for the widespread, closely spaced seismic reflectors (Fig. 2) common in the carbonate oozes and chalks of oceanic plateaus has been studied on the Ontong-Java Plateau (Winterer, Riedel, et al., 1971; Moberly and Heath, 1971; van der Lingen and Packham, 1975) and elsewhere (Schlanger and Douglas, 1974). Laboratory studies of physical properties of Site 289 samples by Milholland et al., 1980 are the most refined ones to date. There was no logging, however, at Site 289, and for Leg 89 it was planned, if time permitted after the HPC, to drill into the ooze/chalk transition and log that hole. Density and velocity logs would give the opportunity to relate the petrography and laboratory-determined physical properties of specimens with downhole measurements of their geophysical parameters. Further, the logs could be processed so that real reflectors could be distinguished from acoustic artifacts. By dating these reflectors paleontologically by their depths in Hole 289, it would then be possible to confirm or reject the hypothesis that reflectors represent paleoceanographic events.

Other objectives of secondary importance included sampling for organic geochemistry, for paleomagnetism, and for diatom biostratigraphy. Periodic use of the heat-flow probe would allow a geothermal gradient to be determined. The origin of the Ontong-Java Plateau and of other oceanic plateaus remains controversial, and every type of high-quality geophysical information is of great value. Finally, if time remained during drilling of the logging hole, it was planned to take some cores from the lower Miocene interval to attempt to resolve a conflict between nannofossil and foraminifer correlations in the lower Miocene of the Pacific area.

Most of the detailed studies of Site 586 material have been made by the Leg 90 Scientific Party and appear in this volume of the *Initial Reports*.

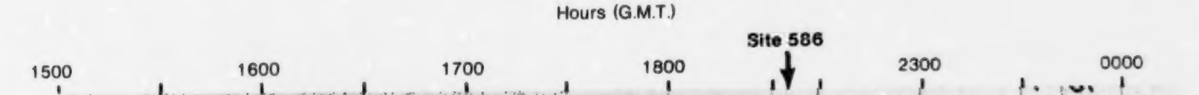

Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 586.

OPERATIONS

The *Glomar Challenger*'s route southwest from Site 462 generally traversed the bathymetric slope that rises up from the Nauru Basin onto the Ontong-Java Plateau. Clear sight of Kusaie (Kosroe) Island and the profiler records of crossings of some of the distributary channels between the plateau and basin confirmed our conclusions about the sources of young ash and reworked Cenozoic fossils that are so abundant in the upper part of the Nauru Basin section at Site 462.

As we approached the position of Site 289 we slowed to 7 knots to improve the seismic reflection record (Fig. 2). There was no need to reoccupy the exact spot of the site, and so the beacon was dropped on a dead reckoning position at 0527 hr. on 19 November. The water depth, corrected from the PDR, was 2207 m. Later, satellite navigation fixes showed that Site 586 is about 1300 m west-northwest of Site 289. The surveying gear was retrieved and the drilling crew commenced to assemble the components for using a variable length hydraulic piston corer (VLHPC) and lowering the drill string.

On the assumption that the seafloor was 2217 m from the drill floor, and taking into account the height of drill pipe joints above the rotary table (for ease in adding new lengths of pipe), the first core was triggered from 2214.8 m. When it was retrieved on board at 1420 hr., only the lower 1.3 m of the 9.6 m "shot" held sediment. The uppermost few centimeters of the core showed brownish colors, indicative of oxidation to the depth of burrowing at the seafloor, above the generally pale greenish colors of reduced pigment in the rest of that core (and of subsequent cores). The sediment/water interface would have been established at 2223.1 m below the drill floor (2213 m below sea level), but the PDR record already mentioned, the Core 586B-1 recovery, and Hole 586C logging indicate that 2218 m below drill floor (2208 m below sea level) is a more correct value for all holes at this site.[3]

Four more cores with virtually complete recovery (99.2%) were easily and speedily obtained from the foraminifer-bearing nannofossil ooze (Table 1). Only the upper half of the sixth core barrel, however, came back on deck, at 1919 hr. on the same afternoon. After the VLHPC inner barrel had been shot hydraulically from its core barrel housing down through the hole in the bit and out into the ooze, it broke off from the barrel and was lost in the sediment. The Von Herzen heat-flow probe with its miniaturized electronics and battery packages was left in the shoe of the lost inner barrel. Because that was the only remaining probe, the heat-flow program ended. The five cores recovered were not oriented, owing to malfunctioning of the Kuster single-shot system.

After that termination of Hole 586, the drill string was raised slightly, then lowered, and Hole 586A was started by washing to the 39.3 m total depth of the first hole. The broken VLHPC was repaired and put to use. The first 25 cores were retrieved from 586A at an average interval of 40 min. from these shallow depths. Virtually all of these cores attempted a full 9.6 m stroke and recovered a full barrel. By 270.6 m coring depth, the frictional resistance to withdrawal of the core barrel from the sediment reached 30,000 to 50,000 lb., and so

Table 1. Coring summary, Site 586.

Core no.	Date (Nov. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 586							
1	19	1420	2218.0-2224.4	0.0-1.3	1.3	1.28	98.5
2	19	1527	2224.4-2233.9	1.3-10.8	9.5	9.52	100.2
3	19	1608	2233.9-2243.4	10.8-20.3	9.5	9.44	99.4
4	19	1701	2243.4-2252.9	20.3-29.8	9.5	9.68	101.9
5	19	1742	2252.9-2262.4	29.8-39.3	9.5	9.06	95.4
					39.3	38.98	99.2
Hole 586A (wash to 39.3 m)							
1	19	2305	2262.4-2272.0	39.3-48.9	9.6	9.45	98.4
2	19	2349	2272.0-2281.6	48.9-58.5	9.6	9.44	98.3
3	20	0043	2281.6-2291.2	58.5-68.1	9.6	9.57	99.7
4	20	0125	2291.2-2300.8	68.1-77.7	9.6	9.54	99.4
5	20	0155	2300.8-2310.4	77.7-87.3	9.6	9.38	97.7
6	20	0237	2310.4-2320.0	87.3-96.9	9.6	9.37	97.6
7	20	0316	2320.0-2329.6	96.9-106.5	9.6	9.52	99.2
8	20	0400	2329.6-2339.2	106.5-116.1	9.6	9.50	99.0
9	20	0445	2339.2-2348.8	116.1-125.7	9.6	9.50	99.0
10	20	0523	2348.8-2358.4	125.7-135.3	9.6	9.40	97.9
11	20	0602	2358.4-2368.0	135.3-144.9	9.6	9.52	99.2
12	20	0640	2368.0-2377.6	144.9-154.5	9.6	9.56	99.6
13	20	0730	2377.6-2384.9	154.5-161.8	7.3	7.30	100.0
14	20	0815	2384.9-2389.8	161.8-166.7	4.9	4.87	99.4
15	20	0900	2389.8-2398.8	166.7-175.7	9.0	9.03	100.3
16	20	0940	2398.8-2408.4	175.7-185.3	9.6	9.56	99.6
17	20	1022	2408.4-2418.0	185.3-194.9	9.6	9.44	98.3
18	20	1105	2418.0-2427.6	194.9-204.5	9.6	9.48	98.8
19	20	1140	2427.6-2436.1	204.5-213.0	8.5	8.54	100.5
20	20	1230	2436.1-2445.7	213.0-222.6	9.6	9.22	96.0
21	20	1305	2445.7-2455.3	222.6-232.2	9.6	9.84	102.5
22	20	1340	2455.3-2464.9	232.2-241.8	9.6	9.50	99.0
23	20	1430	2464.9-2474.5	241.8-251.4	9.6	9.57	99.7
24	20	1512	2474.5-2484.1	251.4-261.0	9.6	9.57	99.7
25	20	1607	2484.1-2493.7	261.0-270.6	9.6	9.47	98.6
26	20	1645	2493.7-2499.7	270.6-276.6	6.0	4.14	69.0
27	20	1750	2499.7-2503.9	276.6-280.8	4.2	4.15	98.8
28	20	1908	2503.9-2508.3	280.8-285.2	4.4	4.26	96.8
29	20	1955	2508.3-2513.3	285.2-290.2	5.0	5.08	101.6
30	20	2050	2513.3-2518.3	290.2-295.2	5.0	5.15	103.0
31	20	2130	2518.3-2523.3	295.2-300.2	5.0	5.11	102.2
					260.9	257.03	98.5
Hole 586B							
1	21	0200	2219.4-2229.0	1.4-11.0	9.6	9.62	100
2	21	0320	229.0-2238.6	11.0-20.6	9.6	9.49	99
3	21	0410	2238.6-2248.2	20.6-30.2	9.6	9.66	100
4	21	0500	2248.2-2257.8	30.2-39.8	9.6	9.31	97
5	21	0545	2257.8-2267.4	39.8-49.4	9.6	9.36	98
6	21	0630	2267.4-2277.0	49.4-59.0	9.6	9.62	100
7	21	0715	2277.0-2286.6	59.0-68.6	9.6	9.10	95
8	21	0800	2286.6-2296.2	68.6-78.2	9.6	9.61	100
9	21	0840	2296.2-2305.8	78.2-87.8	9.6	9.64	100
10	21	0916	2305.8-2314.3	87.8-96.3	8.5	8.01	94
11	21	0950	2314.3-2323.9	96.3-105.9	9.6	9.70	100
12	21	1025	2323.9-2333.5	105.9-115.5	9.6	9.63	100
13	21	1110	2333.5-2343.1	115.5-125.1	9.6	9.69	100
14	21	1145	2343.1-2352.7	125.1-134.7	9.6	9.63	100
15	21	1220	2352.7-2362.3	134.7-144.3	9.6	9.47	99
16	21	1300	2362.3-2371.9	144.3-153.9	9.6	9.41	98
17	21	1348	2371.9-2381.5	153.9-163.5	9.6	9.05	94
18	21	1430	2381.5-2391.1	163.5-173.1	9.6	9.60	100
19	21	1513	2391.1-2400.7	173.1-182.7	9.6	9.60	100
20	21	1550	2400.7-2410.3	182.7-192.3	9.6	9.54	99
21	21	1628	2410.3-2419.9	192.3-201.9	9.6	9.55	99
22	21	1710	2419.9-2429.5	201.9-211.5	9.6	9.63	100
23	21	1749	2429.5-2439.1	211.5-221.1	9.6	9.68	100
24	21	1837	2439.1-2448.7	221.1-230.7	9.6	8.89	93
25	21	1910	2448.7-2458.3	230.7-240.3	9.6	8.44	88
					240.3	234.93	98
Hole 586C							
H1	22	1255	2218.0-2831.5	0.0-613.5	—	—	—
1	22	1350	2831.5-2841.1	613.5-623.1	9.6	2.18	23
					9.6	2.18	23

Note: Data in this table have been corrected to accord with the water depth of 2218 m established by logging at Hole 586C.

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[3] Note that prime data for Holes 586 and 586A collected aboard ship may reflect the originally established water depths and sub-bottom depths and may be in error by 5.1 m in the sub-bottom depths.

to lessen the risk of structural failure of the tool again, the driller shifted to the use of a 5-m-stroke HPC. The last four cores, ending with Core 31 at 300.2 m total depth, were so taken, with excellent results. Coincidentally, the Kuster system provided orientation data for the last cores. Overall there was 98.5% recovery from Hole 586A. The calcareous oozes and, below 230 m, a few thin chalk beds had cored easily. A few more cores probably could have been recovered, but the drill string was pulled up above the seafloor at 0008 hr. on 22 November to maintain the schedule for the site.

After redressing the VLHPC, the crew commenced coring Hole 586B, which was, as earlier noted, to be a duplicate of the 586–586A section, with overlapping depths of individual cores. The first core was shot from 2119.4 m depth, presumably slightly above the 2223.1 m seafloor, with the intention of recovering 5.9 m. The entire 9.6 m barrel, however, was recovered full of sediment, raising the question about the true depth of the seafloor. Again, coring proceeded quickly, with 25 cores obtained in a 17-hr. span. Actually, there were 26 wire line trips in that time; Core 2 had to be repeated when the core catcher failed to close. Orientation was good for these cores; except for the leakage of light, which fogged parts of the film, the Kuster device was working.

When the 25th core was brought on board during the evening of 21 November, it was discovered that the piston had jammed tightly inside the top of the core barrel, because the plastic core liner had collapsed. The lengthy process of removing the core from the barrel, and the additional time that would be needed to remove the piston and redress the tool, caused us to abandon Hole 586B at a total depth of 240.3 m. The average recovery was an excellent 97.8%. The drill string was recovered by 0008 hr. on 22 November.

Hole 586B cores were preserved uncut for the use of Leg 90 scientists. The admixture in the cores from Holes 586 and 586A of transported microfossil components dampened the interest of many of the Leg 89 scientists in using this site for detailed stratigraphy.

Hole 586C was spudded at 0541 hr. with a used bit and a hydraulic bit release in the bottom-hole assembly. More than 600 m of Neogene ooze and chalk were drilled nearly as fast as the pipe could be added to the string. The "wash" core barrel was retrieved with virtually nothing in it, and the only core from Hole 586C, 9.6 m long, with only 23% recovery, ended at 623.1 m total depth. In preparation for logging, the bit was released, and a slurry of fresh water and bentonite mud was pumped into the hole to displace the seawater. The drill string was pulled up close to the seafloor and the derrick was rigged for logging.

Three logging runs were made with the Schlumberger equipment. The logs appear to be excellent. The first run included measurements of sonic velocity, electrical spontaneous potential, electrical induction–spherically focused log, natural gamma radiation, and hole diameter by caliper. Then a second sonde replaced the first one. The other two runs were with that second sonde, but the final log was through a shorter interval and the sonde was pulled up the bore more rapidly. That sonde included measurements of formation density (compensated) and neutron porosity, along with a repeat of the gamma ray and caliper measurements.

All three gamma radiation logs showed, through the drill pipe, the increase above sediment background from ^{234}U and other short-lived isotopes immediately below the seafloor, and then a sharp drop in radiation as the tool was pulled up into seawater. The seafloor in 586C was at about 2218 m. In retrospect, it seems that the filling of Core 586B-1, the gamma ray logs, and the PDR depths were correctly identifying the seafloor at about 2217 or 2218 m from the drill floor (2207 or 2208 m from sea level), and that the 2223.1 m (2213 m from sea level) determination from Core 586-1 may have resulted from some fluke, such as partial loss of the core through a faulty core catcher, or spudding into a depression of the seafloor. A depth of 2218 m has been used for all holes.

After the logging was completed and its rigging removed, the drill string was retrieved and the ship made ready for sea. The ship got under way at 0810 hr. on 23 November, moving northward while streaming the geophysical gear. The *Glomar Challenger* then passed over the beacon, taking water gun records (Fig. 2). Three attempts to obtain ASPER records failed, because of sonobuoys that did not work. They had been stored for about 4 yr. in part of the ship's hold without temperature control; probably their batteries had died months before.

For the next several hours as the vessel crossed the Ontong-Java Plateau, the reflection profiles (e.g., Figs. 3, 4) showed some of the numerous fault scarps that expose older sediment and probably account for some of the sediment reworked into the sediments of Site 586. The vessel continued on a southward course toward the Solomon Islands and on to Noumea.

LITHOLOGIC SUMMARY

Site 586 is located on the Ontong-Java Plateau within 1 nautical mile northwest of DSDP Site 289 at a water depth of 2207 m from sea level. Hole 586 was cored continuously to a sub-bottom depth of 39.3 m. Coring in Hole 586A began at 39.3 m and continued to 300.2 m. The sedimentary section from 0 to 240.3 m sub-bottom was collected again in 25 cores at Hole 586B. The lithostratigraphy of Hole 586B is described in a separate section by the Leg 90 scientists. A fourth hole, Hole 586C, was rotary-drilled for logging to a total depth of 623.1 m sub-bottom. The sediments recovered from Holes 586, 586A, and 586C comprise a single lithologic unit that consists of pale green to white foraminifer–nannofossil ooze and foraminifer-bearing nannofossil ooze and minor chalk of early Miocene to Recent age.

Holes 586 and 586A

The Pleistocene to Recent part of the sedimentary sequence recovered at Site 586 (Cores 586-1 through 586-5) is 39 m thick and contains higher concentrations of foraminifers than the rest of the sequence. These foraminifer-rich sediments contain more than 20% and up to 60% foraminifers (Figs. 5 and 6) and are classified as foraminifer–nannofossil and nannofossil–foraminifer ooze.

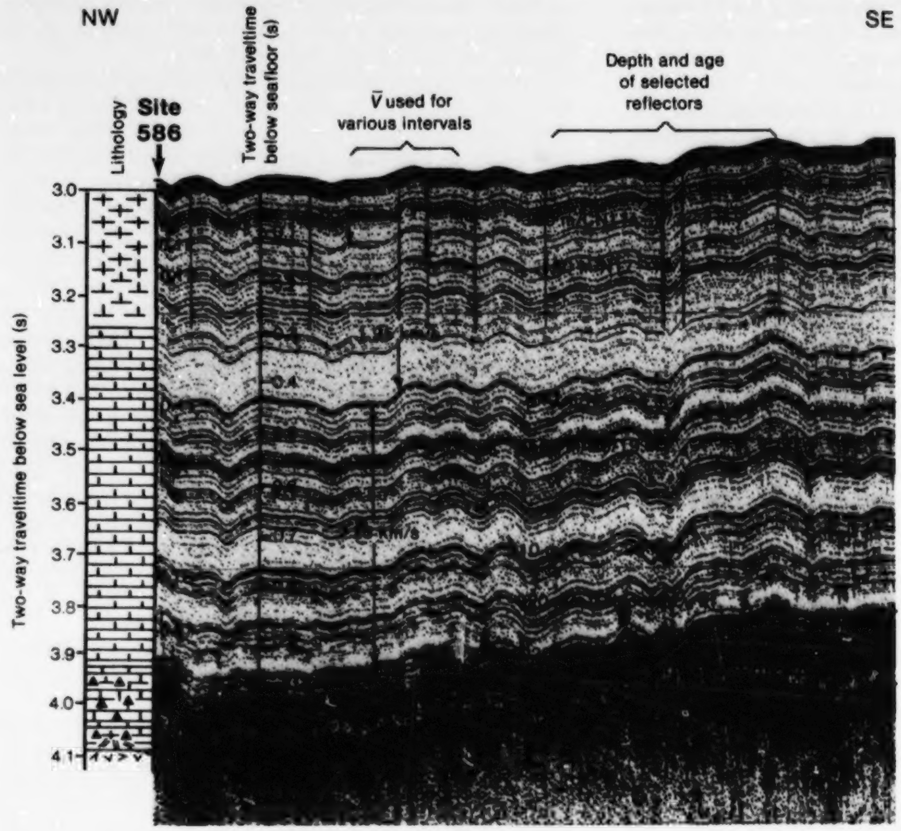


Figure 3. Interpretation of seismic reflection profile at Site 586, northeastern Ontong-Java Plateau. See text for explanation. Source, 80 in.^{3} water gun, 40–160 Hz filter.

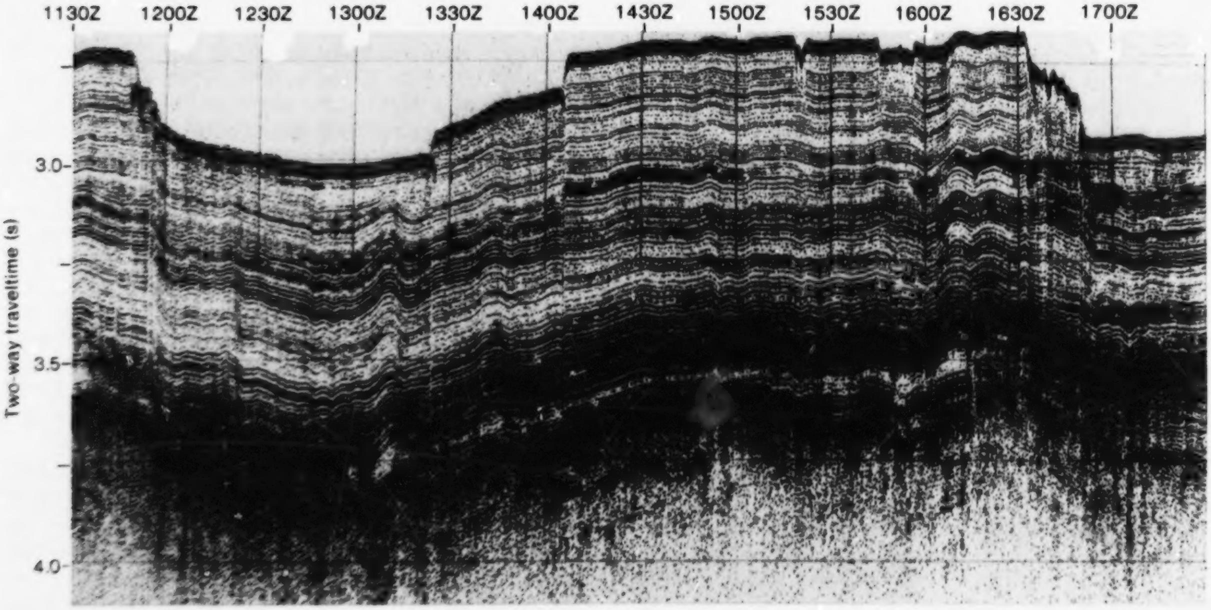


Figure 4. Fault-scarp topography shown by seismic reflection profile near Site 586. Local elevations and slopes such as these may have provided the sediment mixed with the autochthonous sediment at Site 586.

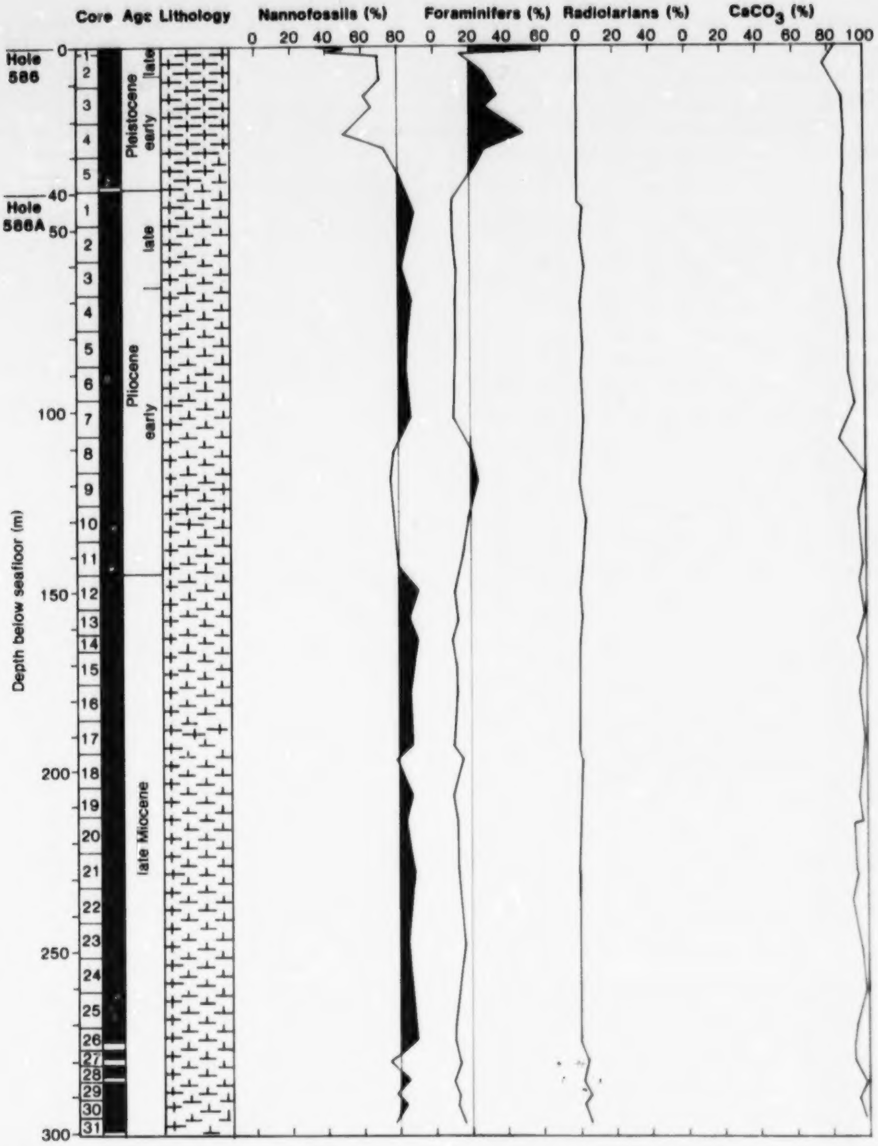


Figure 5. Summary lithology column.

Texturally they are silty clay and sandy silty clay. Sediments recovered in Hole 586A (upper Miocene through Pliocene; 39–300 m sub-bottom) are composed of more than 80% nannofossils and less than 20% foraminifers, and are classified as foraminifer-bearing nannofossil ooze. Results of analyses of 38 samples for $CaCO_3$ range from [illegible] and average 93% (Table 2; Fig. 5). All other components in the sediments are minor (Fig. 6). Siliceous biogenic components, mainly radiolarians and diatoms, are present in minor amounts (up to several percent) throughout the section. They increase in abundance at the base of the recovered section (Figs. 5 and 6), but the total of siliceous biogenic components rarely exceeds 5%. Texturally, all of the upper Miocene to Pliocene sediments are clay or silty clay.

As a result of compaction, the ooze generally does become somewhat stiffer with depth, and nodules of chalk occur within stiff ooze in Cores 586A-25 through 586A-31. Soft, soupy ooze does occur, however, even between some of the chalk nodules in the lower part of Hole 586A. The single core recovered from the base of Hole 586C (613.5–623.1 m, lower Miocene) also consists of interbedded foraminifer-bearing nannofossil chalk and stiff ooze, although some of the ooze is still soft and soupy. The chalk undoubtedly occurs as continuous layers, and its appearance in the cores as nodules is a result of breaking and rounding of the harder chalk layers by the drilling process. There does not appear to be any systematic pattern to the occurrence of the chalk nodules (layers), although chalk nodules in Section 586A-

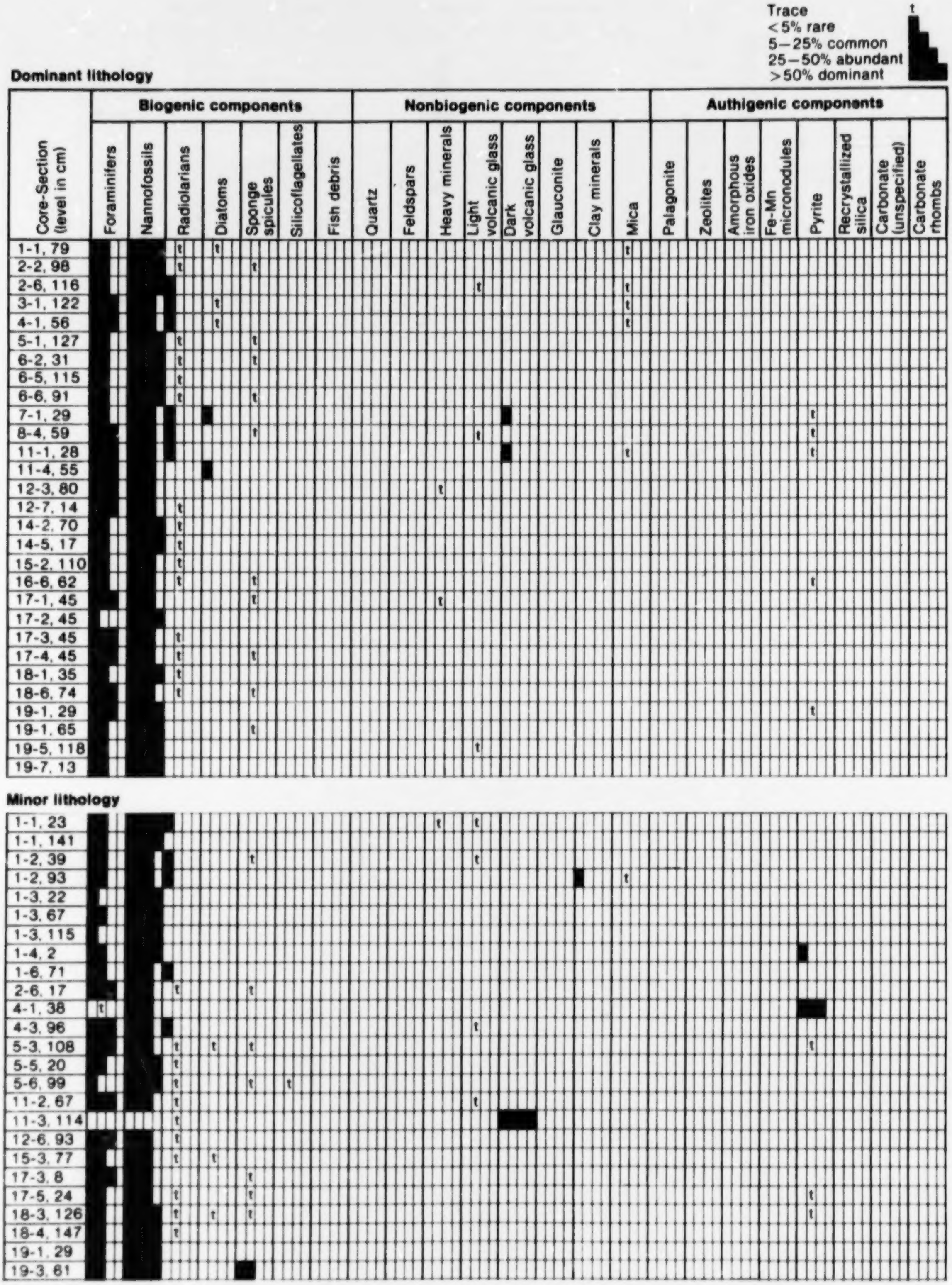


Figure 6. Smear slide summary, Hole 586B.

Table 2. Carbonate bomb results, Holes 586 and 586A.

Core-Section (interval in cm)	Sub-bottom depth[a] (m)	% $CaCO_3$	Lithology
Hole 586			
1-1, 31-32	5.89	84	Nannofossil-foraminifer ooze
2-3, 110-111	10.50	78	Foraminifer-nannofossil ooze
3-3, 76-77	19.66	88	
4-4, 92-94	30.82	89	
5-2, 105-106	37.45	89	
Hole 586A			
1-2, 79-80	45.69	88	Foraminifer-nannofossil ooze
2-1, 75-76	54.75	88	
2-3, 70-71	56.70	88	
3-2, 69-70	65.79	86	
4-2, 48-49	75.18	89	
5-2, 75-76	85.05	90	
6-2, 29-30	94.19	90	
7-2, 35-36	103.85	94	
8-2, 31-32	113.41	85	
9-2, 27-28	122.97	99	
10-2, 30-32	132.60	95	
11-5, 100-101	147.40	97	
12-2, 64-65	152.14	96	
13-2, 60-61	161.70	99	
14-2, 24-25	168.64	95	
15-2, 60-61	173.90	98	
16-2, 70-71	183.00	96	
17-6, 70-71	198.60	99	
18-2, 60-61	202.10	99	
19-3, 49-50	213.09	96	
20-2, 20-21	219.80	98	
20-2, 82-83	220.42	93	
21-4, 108-109	233.28	95	
22-3, 60-61	240.90	92	
23-5, 82-83	253.72	97	
24-6, 145-146	265.45	99	
25-6, 137-138	274.97	94	
26-3, 75-76	279.45	93	
27-2, 105-106	284.25	93	Foraminifer-bearing nannofossil soft ooze and chalk
28-4, 45-46	290.85	99	
29-3, 99-100	294.49	96	Foraminifer-bearing nannofossil ooze and chalk
30-1, 54-55	295.84	96	
31-1, 121-122	301.51	98	

[a] Sub-bottom depths reflect original shipboard calculations and may be in error by 5.1 m.

27-3 seem to occur with a rhythmic spacing of 15 to 20 cm.

The top 15 cm of sediment in Hole 586 has been oxidized to pale brown (5Y 8/1), and probably represents the depth of burrowing, but the rest of the sediments are reduced and have the general overall appearance of very pale green. Sediment colors from the Munsell color chart are white (N9 and 5Y 8/1), bluish white (5B 9/1), pale greenish yellow (5Y 7/3), light greenish gray (5GY 8/1), and various other subtle tints of pale green. Thin layers (mostly less than 1 cm) of slightly darker pale green, pale yellow, and light to medium gray are common above 135 and below 280 m, but mostly these slightly darker colors occur as mottles in highly bioturbated pale green ooze. Many of these darker layers feel somewhat coarser in texture, but textural differences usually cannot be resolved in smear slides. The gray color of some layers and burrow mottles apparently is due to the presence of pyrite, which occurs as small spherical framboids. Compositional differences between the slightly darker green and yellow layers and mottles and the dominant pale green ooze could not be resolved by smear slides, although some qualitative observations suggest that the darker materials may contain slightly higher concentrations of altered volcanic glass and, as mentioned earlier, they tend to be somewhat coarser. In addition to the overall pale green color of the sediment and presence of pyrite, the reduced nature of the sediment is indicated by the odor of H_2S emitted when the cores were opened.

Hole 586B (by Leg 90 shipboard scientific party)

The section at Hole 586B is from one lithostratigraphic unit composed of foraminifer-bearing (5 to 25%) to foraminifer- (25 to 75%) nannofossil ooze (Fig. 6). The color of the major lithology varies from light gray (5Y 7/1) to light greenish gray (5GY 7/1) at the top, grading to very light gray (N8) to white (N9) at the bottom of the section. The recovered section is soft, grading to firm at about 100 m sub-bottom, but it is never firm enough to be classified as a chalk. In general, the sequence is intensely bioturbated. There are several sedimentary features related to the bioturbation including thin burrows (about 0.1 cm thick), larger mottles (about 0.5 cm diameter), and thin, but often very large-diameter (1-20 cm) burrow rinds of light gray (N5 to N7) color. The latter resemble Liesegang rings and probably result from the precipitation of iron sulfide minerals around preferred sites of sulfate reduction such as burrows rich in organic matter. Many of the burrows and other mottles also show color differences from the major lithology and tend toward yellowish grays (5Y 8/1). Blebs of fine-grained iron sulfide (?pyrite) are common throughout the entire section. Very subtle laminations less than 2 cm thick occur throughout the sequence, but in smear slides the lithologies of the laminae appear identical to the surrounding ooze. Numerous thin zones of foraminifer-rich facies were found in the top 45 m, apparently the results of current winnowing. Light greenish gray laminae (5GY 7/1) are common, especially in the top 100 m of the sequence. The greenish color of these laminae is due to disseminated authigenic minerals, among which glauconite was identified as neoformed fillings of foraminifer tests in the lowest core sections and (possibly) celadonite resulting from the diagenetic alteration of volcanic glass in the upper core sections, where trace amounts of volcanic glass also occur.

Severe coring disturbance occurs in Section 586B-3-4 through 586B-3,CC, Section 586B-7-3 through 586B-7,CC, Cores 9 and 10, and Section 586B-13-1 through 586B-13-3, 100 cm.

A comparison of Hole 586B with the shipboard descriptions of Hole 586A shows only minor differences, except for the absence of a near-surface oxidized layer at Hole 586B. Hole 586B did not reach the depth of the chalk nodules found in Hole 586A.

BIOSTRATIGRAPHY

Summary

Holes 586 and 586A

The almost 300 m of sediments recovered in Holes 586 and 586A span the time interval from Recent through almost all of the late Miocene. The three major planktonic groups are well represented throughout and display a moderate to good state of preservation.

As shown by the foraminifer record, the sediments, which at first sight appear to display the sedimentological characteristics of a foraminifer–nannofossil ooze, were affected by mechanical transport, that caused (1) an accumulation of foraminifer tests within the range of the sand fraction and (2) an admixture of forms from different environments, ranging from shallow-water platforms to bathyal depths. Thus, the sediments encountered at this site are transported and are more properly defined as a graded foraminifer–nannofossil silty sand. Evidence of such transport is also shown by the radiolarian assemblages, which display a large variation in the size distribution of the microfauna.

In spite of these sedimentological characteristics, the sedimentary succession appears to be almost continuous, as revealed by the biostratigraphic record. A synthesis of the biostratigraphic succession based on the three fossil groups is shown in Figure 7, where the major events within the foraminifer faunas are also plotted against absolute ages. Some minor reworking of older nannofossils and radiolarians was detected in the upper half of the sequence.

The major biostratigraphic events from the three groups correlate well except for the interval from Cores 586A-3 to 586A-5. There, a major discrepancy concerns the location of the boundary between the early and late Pliocene according to the planktonic foraminifers and calcareous nannofossils. Following the planktonic foraminifers the early/late Pliocene boundary is equated by definition to the last appearance datum (LAD) of *Globorotalia margaritae*, which in Hole 586A occurs between the core-catcher samples of Cores 3 and 4. According to the nannofossils, the same boundary should occur between Zone CN11b and Zone CN12a, which occurs in Core 586A-5 between Sections 4 and 6. Further studies will clarify if such a discrepancy (1) is due to reworking of planktonic foraminifers in higher levels, (2) is related to an erroneous correlation between the two zonal schemes, or (3) is due to the erroneous positioning of the early/late Pliocene boundary with respect to the nannofossil zonal scheme by the nannofossil specialists. The same succession of biostratigraphic events among the planktonic foraminifers, such as the LAD of *Dentoglobigerina altispira* and the first appearance datum (FAD) of *Globigerinoides fistulosus* and of *Globorotalia tosaensis*, was described in the same order by Srinivasan and Kennett (1981) from Site 289 and by Vincent (1981) from Site 463. In addition, they occur within the same nannofossil biozone at the three sites. The third hypothesis of a mislocation of the early/late Pliocene boundary with respect to the nannofossil zonation becomes a real possibility.

Hole 586C

The only core from Hole 586C yielded very well preserved and abundant radiolarian faunas, whereas planktonic foraminifers and calcareous nannofossils are very poorly preserved. All the three fossil groups speak for an early Miocene age. The zonal assemblages in the three groups, however, are not coeval. The possible interpretation is that the planktonic foraminifers are reworked, whereas the nannofossil assemblages are mixed with downhole contaminants. Thus the age based on the radiolarians is retained as the only valid one.

Foraminifers

Holes 586 and 586A

Planktonic foraminifers are abundant in the sediments recovered from Holes 586 and 586A. The washed residues obtained from the core-catcher samples, however, show clear evidence of mechanical transport in the accumulation of foraminifer tests >250 μm, whereas the fraction <250 μm contains a large amount of test fragments, sometimes up to 50% of the total fraction. Moreover, the amount of residue for the 250–150-μm and 150–45-μm fractions is one-half or one-third of the amount obtained from a typical pure nannofossil–foraminifer ooze. Thus, the sediments recovered at Site 586 might better be defined as a planktonic foraminifer silty sand.

Both planktonic and benthic foraminifers from the same sample show different preservation, the same species occurring with transparent and chalk tests. It is not clear if the best preserved tests indicate that the specimens are autochthonous or allochthonous.

In addition, each residue contains few to several specimens of *Quinqueloculina*, coarse agglutinated foraminifers, large nodosariids (one chamber was over 2 mm in size), and highly ornamented ostracodes indicative of an environment much shallower than the present water depth at Site 586 (2208 m below sea level) or than the estimated bathyal paleodepth based on the supposed autochthonous benthic foraminifers. It is worth mentioning that evidence of obvious reworking among planktonic foraminifers could not be detected in this preliminary study, although it cannot be ruled out. In spite of the mechanical transport and mixing of material from shallower depths, the biostratigraphic signal appears to be undisturbed.

The uppermost 39.3 m of the sequence was recovered in Cores 586-1 to 586-5. Below the mud line, the 1 m of Holocene sediments in Core 586-1 yielded a very rich planktonic assemblage. Abundant species include *Globigerina rubescens* (red), *Globigerinoides ruber* (red), *G. mitra* (red), *G. sacculifer, Globorotalia tumida, Pulleniatina finalis*, and *Neogloboquadrina dutertrei*. Traces of sulfur, pyrite, and organic matter partially coat or fill the planktonic foraminifer tests. The core-catcher sample of Core 586-1 belongs to the late Pleistocene Zone N23. The planktonic foraminifer assemblage consists of *G. truncatulinoides, G. crassaformis, G. crassula*, and *Globigerinoides conglobatus*, beside the species mentioned above. The tests of *Globigerina rubescens* and *Globigerinoides ruber* are still red in color.

From Core 586-2 to Section 586-5-6 planktonic foraminifer assemblages are early Pleistocene in age (Zone N22). Common to abundant species are *Globorotalia tumida* and *G. tumida flexuosa, G. truncatulinoides, Pul-*

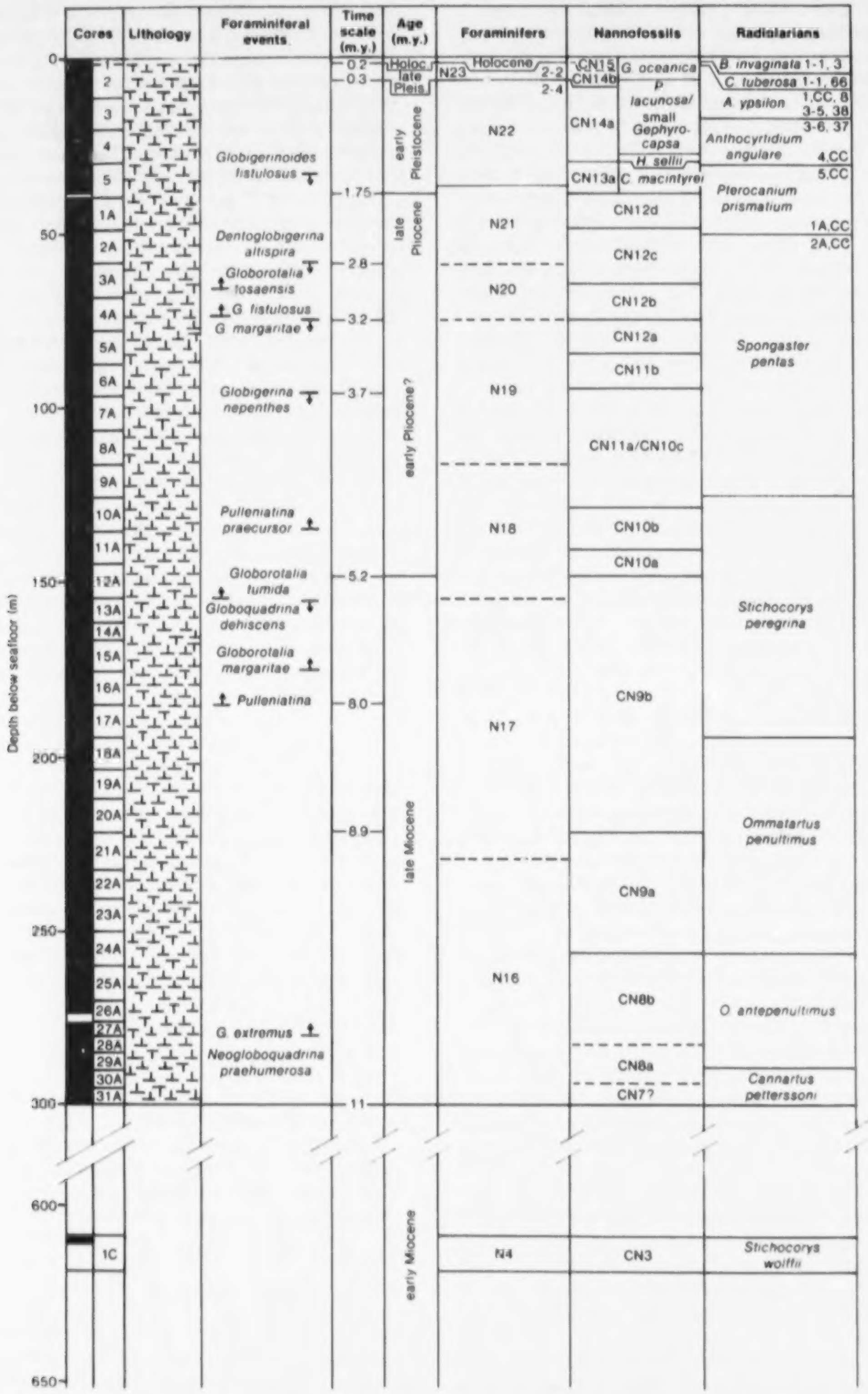


Figure 7. Biostratigraphy of Holes 586 and 586A plotted against lithology and planktonic foraminifer biostratigraphic events calibrated to the absolute ages. Core recovery in black. A after core number indicates Hole 586A Cores.

leniatina obliquiloculata, Globigerinoides ruber (white), and *G. sacculifer*, among others. Few specimens of *Globorotalia tosaensis* and *Globigerinoides* aff. *fistulosus* and the unusual abundance of *Streptochilus tokelauae* in Sample 586-4,CC indicate early Zone N22. The late Pleistocene planktonic assemblage of Zone N21 occurs in core-catcher Sample 586-5,CC (the last core in Hole 586) and in Cores 586A-1 and 586A-2, where coring started at the same level at which Hole 586 was discontinued. This zonal assemblage is characterized by the occurrence of *Pulleniatina obliquiloculata, Globorotalia tosaensis, T. tenuitheca, G. crassaformis*, and by common to abundant *Globigerinoides fistulosus* and *Streptochilus tokelauae*. Accompanying species are *Globorotalia tumida, G. tumida flexuosa, G. exilis, G. ungulata*, sphaeroidinellids, *Globigerinoides ruber*, and rare *G. extremus*.

The core-catcher sample of Core 586A-3 yielded a planktonic foraminifer assemblage similar to those occurring in the overlying Cores 586A-1 and 586A-2 except for the occurrence of common, well-developed specimens of *Dentoglobigerina altispira*. According to Blow (1969) the latter taxon should not co-occur with *Globorotalia tosaensis* and *G. tenuitheca*, which are also present in Core 586A-3,CC. Further studies will clarify if the range of *D. altispira* in fact overlaps with that of *G. tosaensis* and *G. tenuitheca* or the occurrence of *D. altispira* in Core 586A-3,CC is anomalous and due to reworking. For the time being, Core 3 is attributed to Zone N20, the oldest zone in the late Pliocene.

The interval from Cores 586A-4 to 586A-8 is attributed to the early Pliocene Zone N19 on the basis of the occurrence of *Globorotalia margaritae* with *Pulleniatina obliquiloculata, Dentoglobigerina altispira, Globorotalia tumida, G. tumida flexuosa, Neogloboquadrina humerosa*, and *Globigerinoides extremus*, and including *Streptochilus tokelauae*, which was limited to core 586A-4. The planktonic foraminifer assemblages in Cores 586A-7 and 586A-8 are differentiated from those contained in Cores 4 to 6 by the occurrence of *Globigerina nepenthes, Pulleniatina spectabilis, P. praecursor*, and *Streptochilus latum. Globorotalia margaritae* is very rare in some samples. The boundary between Zones N19 and N18, still early Pliocene in age, is tentatively placed between Cores 586A-8 and 586A-9, based on a single specimen of *Sphaeroidinella* that occurs in Core 586A-8,CC. (*Sphaeroidinellopsis* and *Sphaeroidinella* are rare components of most of the assemblages recovered at Site 586.) The interval from cores 586A-9 through 586A-12 yielded a planktonic foraminifer fauna characteristic of Zone N18 of latest Miocene to early Pliocene age. The lower boundary of Zone N18 corresponds to the FAD of *Globorotalia tumida* in the evolutionary transition from *G. plesiotumida*, which occurs in Core 586A-12,CC. Two biostratigraphic events occur in this zone. The first is the FAD of *Pulleniatina praecursor* in Core 586A-10, an early Pliocene event, whereas the second event corresponds to the LAD of *Globoquadrina dehiscens*. The latter event is equated with the Miocene/Pliocene boundary (Berggren, 1977). Common species in Zone N18 are *Neogloboquadrina humerosa, N. acostaensis, Globigerina nepenthes, Pulleniatina primalis, P. spectabilis, Globorotalia scitula, G. cultrata, Globigerinoides sacculifer, G. extremus, G. obliquus, D. altispira, G. baroemoenensis*, and *Streptochilus latum*.

The interval from Cores 586A-13 to 586A-20 yielded a planktonic foraminifer assemblage characteristic of the late Miocene Zone N17, the lower boundary of which corresponds to the FAD of *Globorotalia plesiotumida* evolving from *G. merotumida*. The major biostratigraphic event within Zone N17 is the FAD of *Pulleniatina* s.l., which occurs in Core 586A-16. Rare specimens of *Globorotalia margaritae* are recorded from Core 586A-15 upward. Beside the events mentioned above, the assemblages of Zone N17 are similar to those of Zone N18.

The interval from Core 586A-21 to total depth (Core 586A-31) contains planktonic faunas attributable to the late Miocene Zone N16. Two major biostratigraphic events occur within this zone: the FAD of *Neogloboquadrina humerosa*, evolving from *N. acostaensis*, and of *Globigerinoides extremus*, that evolves from *G. obliquus* in Core 386A-27. Common species in this interval include the index species *N. acostaensis* and *Globorotalia merotumida, Globigerina nepenthes, Globorotalia cultrata* (which is very abundant in some samples), *Globigerinoides obliquus, G. sacculifer, Dentoglobigerina altispira, G. baroemoenensis, G. dehiscens*, and *Streptochilus latum*.

Globoquadrinids, *Globorotalia lenguaensis*, and *G. praelenguaensis* are particularly abundant in the two lowermost cores.

Holes 586C

Only one core was recovered from Hole 586C in addition to a washed core at the sub-bottom depth of 608 m. Planktonic foraminifers are abundant but very poorly preserved. Rare *Globigerinoides immaturus* and common *Globorotalia kugleri* and *G. pseudokugleri* are associated with large globigerinids, primitive *Dentoglobigerina altispira, Globoquadrina praedehiscens*, and very rare *G. binaiensis*. This assemblage is characteristic of the upper part of Zone N4, which is early Miocene in age. Reworked Oligocene faunas may be present.

Nannofossils

Holes 586 and 586A

Core-catcher samples from Holes 586 and 586A were examined to provide an outline of the nannofossil biostratigraphy. Smear slide preparations were made from intervals within cores when it was necessary to locate zonal boundaries and important datums. Nannofossils are abundant in every sample examined. A reduction in the nannofossil content was seen in samples from Core 586-4, the top of Core 586A-2, and the base of Core 586A-1. The preservation of assemblages fluctuates between moderate and good, although there was an overall decrease in the quality of preservation downhole. This deterioration in preservation is represented as overgrowths on the discoasters in lowermost Pliocene and upper Miocene sediments. Discoasters in samples from Cores 586A-12 through 586A-16 are slightly to moderately overgrown and those in sediments below these cores are moderately to heavily overgrown. Heavy overgrowths on certain species in Cores 586A-25 through 586A-31 made identification of these forms difficult. Placoliths are well preserved throughout and are only slightly etched in samples where the discoasters are overgrown. Sample 586A-28-4, 36–37 cm, in which there are over 10% diatoms, contains a well-preserved assemblage with little overgrowth of the discoasters. Samples above and below this level contain less than 1% diatoms. Thus, the amount of noncalcareous constituents in these samples may influence the extent to which diagenesis may alter the nannofossil assemblages. Problems in identification caused by these overgrowths led to uncertainties in the biostratigraphy in the bottom of the hole, because many of the discoasters are utilized as datums in the late Miocene.

Figure 8 shows the nannofossil datums, along with the zonation schemes of Okada and Bukry (1890), Ellis (1982), Martini (1971), and Gartner (1977), graphed in relation to the cores recovered in Holes 586 and 586A. The section appears to be continuous, as all the nannofossil zones from the *Discoaster hamatus* Zone through the *Emiliania huxleyi* Zone are present. The only reworking detected was in Cores 586A-7 through 586A-9, where some late Miocene discoasters were reworked into Pliocene sediments. Some of the zonal boundaries in the biostratigraphic zonations mentioned above could not be accurately determined. The first occurrence of *Emiliania huxleyi* could extend much lower than indicated, because this species is best identified on the electron microscope. If so, it is possible that a hiatus may be present within the upper Pleistocene sediments in Cores 586-1 and 586-2. The first appearances of *Gephyrocapsa caribbeanica* and *G. oceanica*, which are used as successive datums in the early Pleistocene by Okada and Bukry (1980) and Ellis (1982), are synchronous in this section, and the *G. caribbeanica* Subzone (CN13b/WPN30b) could not be recognized. It is more likely that this is a problem inherent in these stratigraphies rather than an indication of a hiatus in this section (see Gartner, 1977). There is, however, the possibility that part of Core 1 was lost through the core catcher (see Operations section).

Amaurolithus tricorniculatus did not occur in any of the samples examined. Both Okada and Bukry (1980) and Martini (1971) use the last occurrence of this species in lower Pliocene sediments to define a zonal boundary, and so some resolution is lost when applying these zonations to this section. Ellis (1982) also found this to be true in sediments from the Mariana Trench and used the acme of *Sphenolithus neoabies* to resolve the boundary problem between the *Sphenolithus neoabies* Subzone and *Ceratolithus rugosus* Subzone. The extinction of *A. primus* is used in conjunction with that of *A. tricorniculatus* in the Okada and Bukry (1980) zonation to define this same boundary. This species is restricted to the *Amaurolithus primus* Subzone in these cores, except for Sample 586A-9-4, 36–37 cm, into which it is reworked with other late Miocene species. The last occurrence of this species in upper Miocene sediments at Sites 541 and 542 in the equatorial Atlantic is further evidence that this early Pliocene datum is not reliable.

Problems were also encountered in locating the lower boundary of the *Discoaster quinqueramus* Zone. It has been placed within core 586A-24 at the first occurrence of *Discoaster berggrenii* because all three zonal schemes recognize this datum. The first occurrence of *D. surculus*, which is used in addition to *D. berggrenii* by both Okada and Bukry (1980) and Ellis (1982), is first seen in core 586A-26. The rarity of this species in Cores 586A-25 and 586A-26 and the overgrowths that obscure its bifurcate tips make this datum hard to locate. Ellis (1982) also recognized the extinction of *D. bellus* and *D. neohamatus* at this boundary. These two species, although rare, are found in Core 586A-23 above the first occurrence of *D. berggrenii*. The last common occurrence of *D. bellus*, however, is coincident to the entry of *D. berggrenii*.

A few specimens of *D. hamatus* (five rays) were found in Samples 586A-30,CC and 586A-31,CC, and these sediments are tentatively placed in the *D. hamatus* Zone. *D. neohamatus* is common in these samples, whereas *D. bellus* and *D. pentaradiatus* are rare. Ellis (1982) uses the first occurrence of *D. pentaradiatus* to mark the top of the *D. hamatus* Zone. Thus, it appears that the top of the *D. hamatus* Zone was reached in Core 586A-31, or it may be that these extremely rare specimens of *D. hamatus* are reworked. Species of the genus *Catinaster*, which are normally found in sediments of those ages, are not present.

Radiolarians

For Site 586 one sample per section was studied for the first four cores; only the core-catcher samples were examined from Cores 586-4 to 586A-31 and 586C-1.

For the biostratigraphic zonation we followed Nigrini (1971) for the Quaternary, and Riedel and Sanfilippo (1978) for the remainder of the Cenozoic. The use of the evolutionary transition from *Lamprocyrtis neoheteroporos* to *L. nigrinae* instead of the upper morphotypic limit of *Pterocanium prismatium* is adopted here for the definition of the upper limit of the *Pterocanium prismatium* Zone. This change greatly reduces the range of the *Anthocyrtidium angulare* Zone. Because *Spongaster berminghami* is rare, we have adopted the first appearance of *P. prismatium* to define the base of the *Spongaster pentas* Zone. This datum is essentially synchronous with that of the standard zonation.

The preservation of the radiolarian fauna is moderate except for some levels where the specimens are broken (Cores 586-2, 586A-6, and 586A-13). The abundance of the fauna permits us to recognize three assemblages: (1) Core 586-1 with a common fauna; (2) Cores 586-2 to 586A-14 with a few to common fauna; (3) Cores 586A-15 to 586A-31 and 586C-1 with a common to abundant fauna, often accompanied by diatoms.

The uppermost Quaternary radiolarian zone, *Buccinosphaera invaginata*, was identified in Sample 586-1-1, 2–3 cm. Sample 586-1-1, 66–67 cm is related to the *Collosphaera tuberosa* Zone. *Amphirhopalum ypsilon* Zone extends from Samples 586-1,CC to 586-3-5, 37–38 cm. Some reworked specimens from the lower Pleistocene occur in Core 586-3. The *Anthocyrtidium angulare* Zone

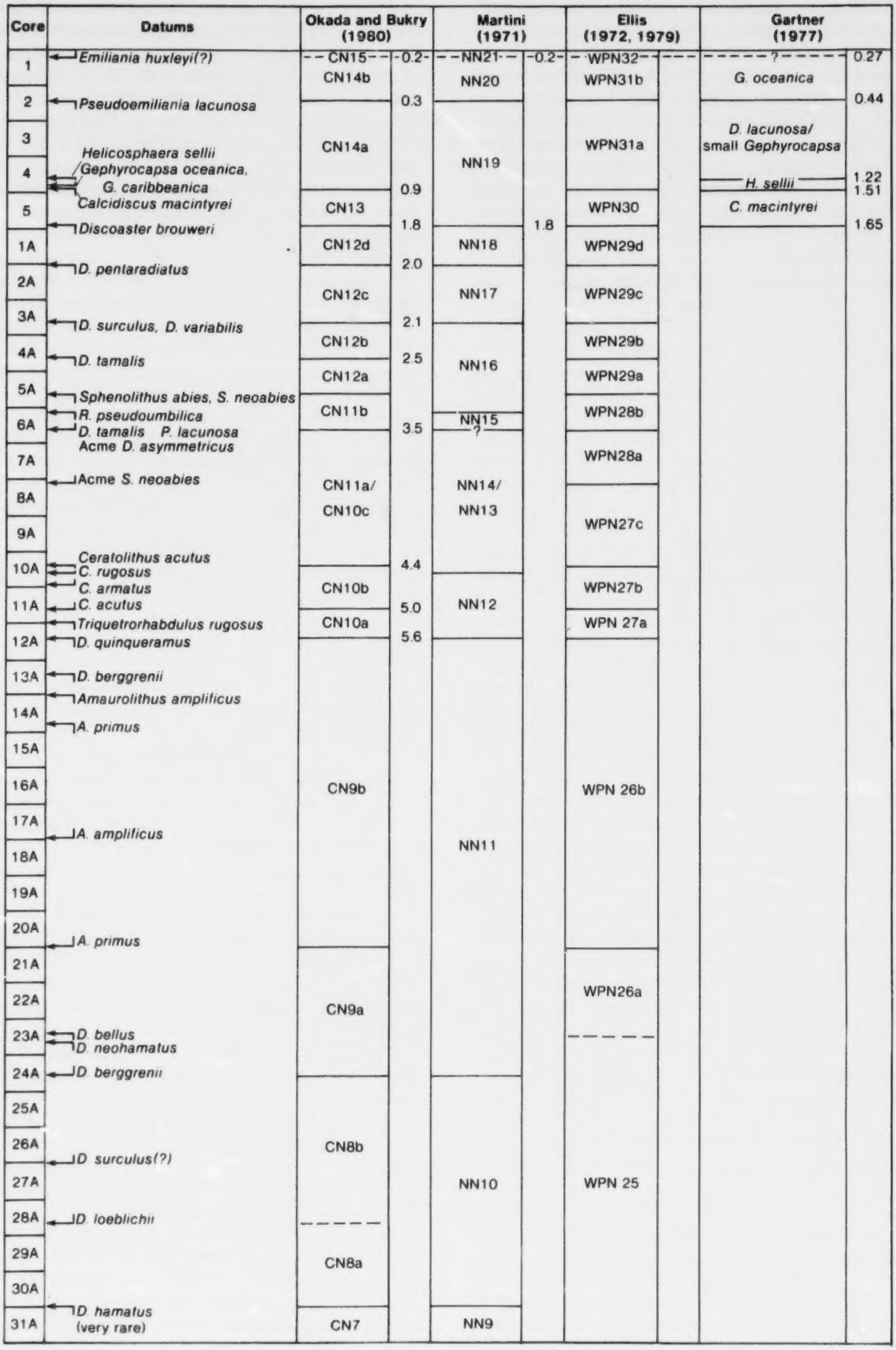

Core
Datums
Okada and Bukry (1980)
Martini (1971)
Ellis (1972, 1979)
Gartner (1977)
1
2
3
4
5
1A
2A
3A
4A
5A
6A
7A
8A
9A
10A
11A
12A
13A
14A
15A
16A
17A
18A
19A
20A
21A
22A
23A
24A
25A
26A
27A
28A
29A
30A
31A
Emiliania huxleyi(?)
Pseudoemiliania lacunosa
Helicosphaera sellii
Gephyrocapsa oceanica,
G. caribbeanica
Calcidiscus macintyrei
Discoaster brouweri
D. pentaradiatus
D. surculus, D. variabilis
D. tamalis
Sphenolithus abies, S. neoabies
R. pseudoumbilica
D. tamalis P. lacunosa
Acme D. asymmetricus
Acme S. neoabies
Ceratolithus acutus
C. rugosus
C. armatus
C. acutus
Triquetrorhabdulus rugosus
D. quinqueramus
D. berggrenii
Amaurolithus amplificus
A. primus
A. amplificus
A. primus
D. bellus
D. neohamatus
D. berggrenii
D. surculus(?)
D. loeblichii
D. hamatus
(very rare)
CN15
CN14b
CN14a
CN13
CN12d
CN12c
CN12b
CN12a
CN11b
CN11a/
CN10c
CN10b
CN10a
CN9b
CN9a
CN8b
CN8a
CN7
0.2
0.3
0.9
1.8
2.0
2.1
2.5
3.5
4.4
5.0
5.6
NN21
NN20
NN19
NN18
NN17
NN16
NN15
?
NN14/
NN13
NN12
NN11
NN10
NN9
0.2
1.8
WPN32
WPN31b
WPN31a
WPN30
WPN29d
WPN29c
WPN29b
WPN29a
WPN28b
WPN28a
WPN27c
WPN27b
WPN 27a
WPN 26b
WPN26a
WPN 25
?
G. oceanica
D. lacunosa/
small Gephyrocapsa
H. sellii
C. macintyrei
0.27
0.44
1.22
1.51
1.65

Figure 8. Nannofossil datums, Holes 586 and 586A.

extends from Core 586-3-6, 36–37 cm to 586-4,CC; *Pterocanium prismatium* Zone from 586-5,CC to 586A-1,CC; *Spongaster pentas* Zone from 586A-2,CC to 586-9,CC; *Stichocorys peregrina* Zone from 586A-10,CC to 586A-17,CC; *Ommatartus penultimus* Zone from 586A-18,CC to 586A-23,CC; *O. antepenultimus* Zone from 586A-24,CC to 586A-29,CC; and the *Cannartus petterssoni* Zone was found below 586A-30,CC. Core 586C-1 is from the *S. wolffii* Zone.

There is a large variation in the size of the microfauna. The size fraction >150 μm is large in some samples and small in others. For example, in 586A-8,CC less than 1% of the assemblage is >150 μm. A high percentage of small tests can be interpreted to result from an allochthonous, transported fauna; a high percentage of large tests indicates an autochthonous fauna.

Summary, Hole 586B (completed by Leg 90 scientists)

The 240.3 m of sediments recovered in Hole 586B were dated as Quaternary to late Miocene. Although only a limited number of samples were examined, there appears to be no evidence of any stratigraphic break. The following groups of fossils were recorded: planktonic and benthic foraminifers, calcareous nannofossils, diatoms, silicoflagellates, and radiolarians.

No evidence of reworking was found in the planktonic foraminifers and only one specimen of displaced *Discoaster hamatus* was found in Sample 586B-21,CC.

Foraminifers, Hole 586B

Planktonic foraminifers are both abundant and well preserved in samples from Cores 586B-2 through 586B-25. There is no evidence of reworking, which has been suggested for the faunas and floras of Holes 586 and 586A.

The *Globorotalia truncatulinoides* Zone (= N22) yielded a rich fauna, as, for example, in Core 586B-2, which included the zone fossil and the following index taxa: *Globorotalia menardii* (sinistral) (= *G. cultrata*), *Pulleniatina obliquiloculata* (dextral), *Sphaeroidinella dehiscens, Neogloboquadrina dutertrei* (d), and *Globigerinoides ruber.*

In Cores 586B-5-1 through 586B-8-5, the *Globigerinoides fistulosus* Zone (= N21) yielded the following index species: the zone fossil, *Globorotalia tosaensis, G. tumida* (s), *S. dehiscens, P. obliquiloculata* (d), and *Globigerinoides extremus.*

The *Neogloboquadrina humerosa* Zone (= N19–N20) was found in Cores 586B-8-6 through 586B-13-7; important species include *Globoquadrina altispira, Globorotalia tumida, P. primalis, P. spectabilis, Globigerinoides extremus, Globigerina decoraperta*, and *Neogloboquadrina humerosa*. No. *Globorotalia margaritae* were found in the samples.

The *Globorotalia tumida* Zone (= N18) was found in Core 586B-17; a relatively low diversity fauna yielded the following diagnostic taxa: the zone fossil, *N. acostaensis, G. juanai*, and *P. primalis* (s).

The *Pulleniatina primalis* Zone (= N17b) was encountered in Sample 586B-17-6, with the following diagnostic species: the zone fossil, *Globorotalia plesiotumida* (d), *Globoquadrina dehiscens*, and *Sphaeroidinellopsis paenedehiscens.*

The *Globorotalia plesiotumida* Zone (= N17a) was recorded from Section 586B-21-5 through 586B-25-5 with the zone fossil, *Globoquadrina dehiscens, N. acostaensis*, and *S. seminulina.*

Benthic foraminifers were examined from ten samples through cores 5 and 6; each sample was taken from a different lithology or colored interval in the two cores. The foraminifers, generally accompanied by radiolarians, were highly fragmented in samples from the green, tan, olive, and gray white intervals, whether of coarser of finer texture. Only the gray, fine-grained layers contain little evidence of fragmentation. Typical species are *Uvigerina auberiana, U. proboscidea, Nonion barleanum, N. pompiliodes, Pullenia bulloides, Eggerella bradyi*, and *Pyrgo murrhina*. Several broken specimens of *Quinqueloculina* were found only in the green layers, in which fragmentation is very intense. Other than the *Quinqueloculina* specimens, the benthic foraminifers appear to be in place.

Calcareous Nannoplankton, Hole 586B

Core-catcher samples and enough other samples accurately to determine zonal boundaries were examined for calcareous nannoplankton. Hole 586B ranges in age from late Pleistocene to late Miocene and includes all the calcareous nannoplankton zones (NN21 to NN11a).

Pleistocene

The occurrence of *Emiliania huxleyi* in Sample 586B-1, top, places this sample in the late Pleistocene *Emiliania huxleyi* Zone (NN21).

The late Pleistocene *Gephyrocapsa oceanica* Zone (NN20) occurs between the last occurrence of *E. ovata* in Sample 586B-1-5, 30–31 cm and the first occurrence of *E. huxleyi* and includes Samples 586B-1-3, 30–31 cm and 586B-1-4, 30–31 cm.

The presence of *E. ovata* and the absence of *Calcidiscus macintyrei* in Samples 586B-1-5, 30–31 cm to 586B-4-2, 30–31 cm place these samples in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The lower subzone (NN19a) includes the interval from Samples 586B-4-3, 30–31 cm to 586B-5-2, 30–31 cm, above the last occurrence of *Discoaster brouweri* in Sample 586B-5-3, 30–31 cm.

Pliocene

The presence of *Discoaster brouweri* and the absence of *D. pentaradiatus* in Samples 586B-5-3, 30–31 cm to 586B-6-4, 30–31 cm places this interval in the late Pliocene *Discoaster brouweri* Zone (NN18). The presence of *D. pentaradiatus* and the absence *D. surculus* in Samples 586B-6-5, 30–31 cm and 586B-6-6, 30–31 cm places these samples in the late Pliocene *D. pentaradiatus* Zone (NN17). The interval from Sample 586B-6-7, 30–31 cm to 586B-8,CC, above the last occurrence of *Reticulofenestra pseudoumbilica* in Sample 586B-9,CC, is placed in the late Pliocene *D. surculus* Zone (NN16). The interval from Sample 586B-9,CC to 586B-13-7, 30–31 cm, above the last occurrence of *Amaurolithus tricorniculatus* in Sample 586B-13,CC, is placed in the early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). The first occurrence of *D. asymmetricus* in Sample 586B-15-1, 30-31 cm places Samples 586B-13,CC to 586B-15-1, 30-31 cm in the early Pliocene *D. asymmetricus* Zone (NN14). The first occurrence of *Ceratolithus rugosus* in Sample 586B-15,CC places Samples 586B-15-2, 30-31 cm to 586B-15,CC in the early Pliocene *Ceratolithus rugosus* Zone (NN13). The interval from Samples 586B-16-1, 30-31 cm to 586B-17,CC, above the last occurrence of *D. quinqueramus* in Sample 586B-18-1, 30-31 cm, is placed in the early Pliocene *Amaurolithus tricorniculatus* Zone (NN12).

Miocene

The presence of *Discoaster quinqueramus* together with *Amaurolithus primus* in Samples 586B-18-1, 30-31 cm to 586B-21-4, 30-31 cm places this interval in the upper subzone of the late Miocene *Discoaster quinqueramus* Zone (NN11b). The absence of *A. primus* and the presence of *D. quinqueramus* in Samples 586B-21-5, 30-31 cm to 586B-25,CC places this interval in the lower subzone of the *D. quinqueramus* Zone (NN11a).

Diatoms and Silicoflagellates, Hole 586B

Diatoms were noted in low numbers in Samples 586B-4,CC through 586B-8,CC, of late Pliocene-early Pleistocene age. Among them the large diatom *Ethmodiscus rex* is present in Samples 586B-5,CC and 586B-8,CC. Rare to few diatoms were found in the lower lower Pliocene Samples 586B-14,CC through 586B-16,CC, and in the upper Miocene Samples 586B-22,CC and 586B-25,CC. In Samples 586B-4,CC and 586B-6,CC rare silicoflagellates were encountered.

Radiolarians, Hole 586B

Radiolarian fragments were observed during smear slide analysis at various levels.

SEDIMENTATION RATES

Sedimentation rates for Holes 586 and 586A are shown in Figure 9. In Figure 10 sedimentation rates for Hole 586C are shown from 305 m sub-bottom to total depth of 623.1 m. For the upper part, sedimentation rates are those from the previous holes, plotted at a different scale.

Accumulation rates vary consistently throughout the sequence drilled in the first two holes. The maximum rate occurred in the latest early Pliocene (from 3.7-3.2 m.y. ago) when sediments accumulated at a rate of about 54 m/m.y. A minimum rate of 13 m/m.y. occurred in the latest Miocene, between 8 and 5.2 m.y. ago.

In the younger part of the sequence sediments were deposited at rates ranging from 25 to 20 m/m.y. Rates of ~37 m/m.y. were calculated for the remaining part of the early Pliocene and the early late Miocene.

The lower part of the sequence was deposited at an average rate of ~39 m/m.y. (Fig. 10). Details cannot be determined because Hole 586C was washed nearly to its total depth.

ORGANIC GEOCHEMISTRY

The organic carbon contents were determined for two samples from Hole 586 and 14 samples from Hole 586A, covering the cored section down from 0 to 296 m below seafloor. For analytical details see the organic geochemistry section in the Site 585 summary chapter (Leg 89 *Initial Report;* Moberly, Schlanger, et al., in press). As obvious from the data summarized in Table 3, the organic carbon contents vary from 0.62% (based on dry sediment weight) to less than 0.01% (i.e., below detection limit). The higher values are found in the upper part of the section penetrated (mean value of 0.35% for Cores 586-1, 586-5, 586A-1 to 586A-8). An abrupt decrease in organic carbon contents occurs between Cores 586A-8 and 586A-9. From Core 586A-9 downward the values remain very low (0.03% and less) throughout the hole to total depth. The elevated organic carbon contents in the uppermost 115 m of this drill site exceed the minimum threshold value commonly required for petroleum source rocks of the carbonate or evaporite facies (0.3%). The organic carbon contents of these samples, however, should be verified by shore-based independent analyses. The discussion of analytical limitations of the CHN-Analyzer and sample pretreatment procedures in the Organic Geochemistry section of the Site 585 summary chapter should be noted (Moberly, Schlanger, et al., in press).

The elevated organic carbon contents found from 0 to 115 m depth are associated with relatively lower $CaCO_3$ contents of the sediments (84-90%), as compared to Cores 586A-9 to 586A-30, where $CaCO_3$ contents in excess of 93% (in some even 99%) were measured.

INORGANIC GEOCHEMISTRY

Tables 4 and 5 and Figure 11 constitute this report; there is no text.

PALEOMAGNETICS

Hole 586B (by Leg 90 shipboard scientific party)

Holes 586 and 586A were subsampled for paleomagnetic analysis by Leg 89 personnel and have yet to be measured. NRM measurements have been made on two specimens per section from Hole 586B using a cryogenic magnetometer, with geometric mean intensity = 0.058 μG; scalar mean inclination = $-0.41 \pm 35.6°$s.d.; axial dipole inclination = $-1.0°$; and mean angle between repeat measurement = 6.5°.

A zone of relatively strongly magnetized sediment (2.5 to 7.5 μG) occurs at the top of the sequence above 586B-1-6, 27 cm (7.77 m depth). Intensities drop rapidly to values of typically 0.05 μG below the middle of Core 2. Fairly high intensity spikes are common, the most prominent being listed in Table 6. These spikes are not associated with any obvious macroscopic changes in the sediment.

Below the high-intensity zone in Core 1 directions become highly scattered. Inclination data cannot be used to infer polarity as the site is too close to the equator. Unfortunately, there were no orientation data for these cores. The random scatter in inclinations indicates that the primary remanence signal was not being observed. Declinations can be used to infer the presence of only

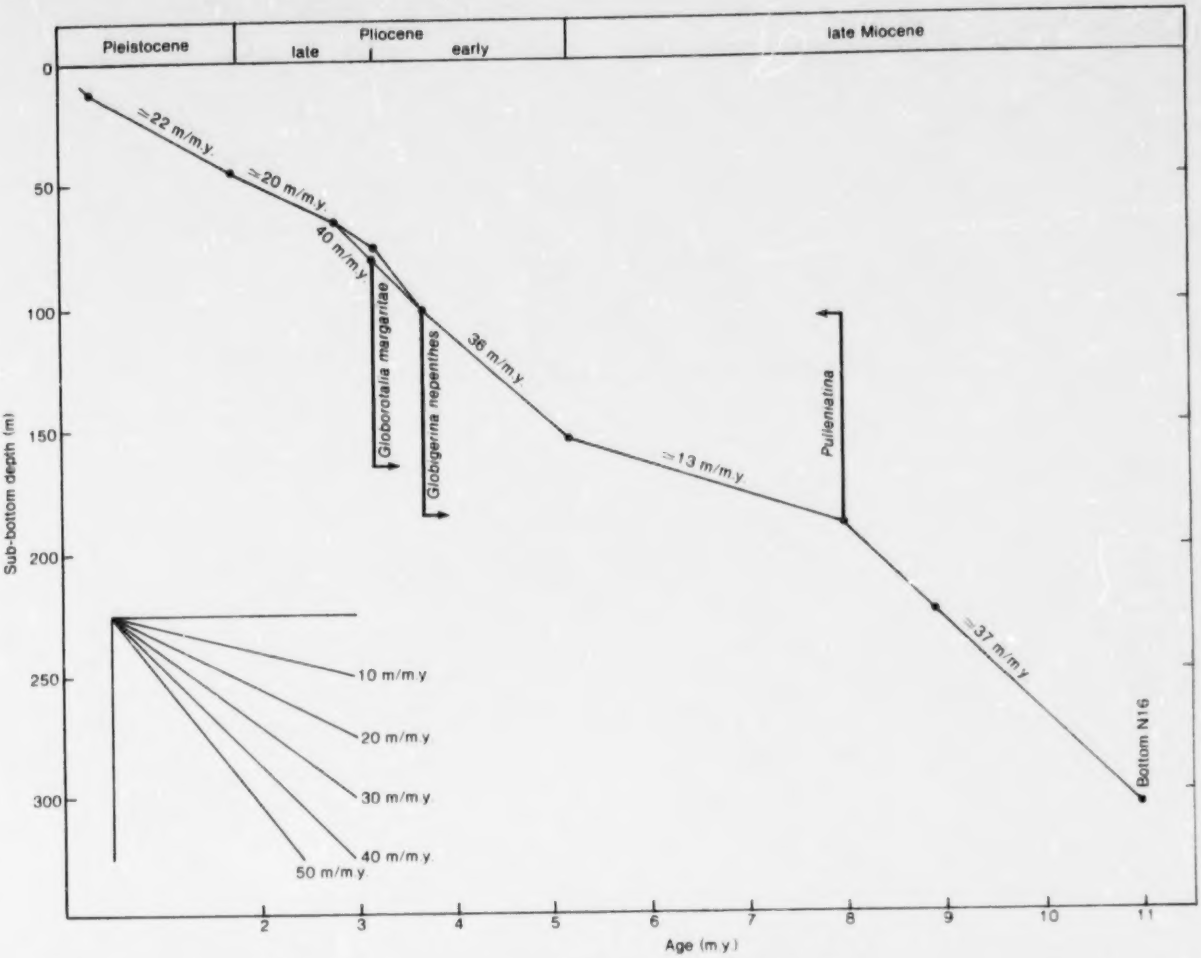


Figure 9. Sedimentation rates of Holes 586 and 586A. Data points according to planktonic foraminifers.

one polarity transition, the Brunhes/Matuyama boundary (0.73 m.y. ago) between Sections 586B-2-3 and 586B-2-4 (12.85–15.10 m).

PHYSICAL PROPERTIES

Compressional wave velocity measurements (V_p) were made on whole core samples in the liner for every section from 586A-22-5 to 586A-31-3 and for one section of each core from 586B-1 to 586B-25, after the temperature of the cores equilibrated with that of the core lab. These measurements are of the horizontal (parallel to bedding) V_p. Continuous GRAPE measurements were made on every other section of cores from Holes 586 and 586A, and on almost all sections from Hole 586B. Using samples taken with a minicore-sized metal cylinder, water content, porosity, and wet-bulk density were measured by means of the gravimetric method on one sample every other section in Hole 586A. All methods used in these measurements are described in Boyce (1976a).

All measured values except those of wet-bulk density by the continuous GRAPE are listed in Table 7. Values of wet-bulk density corresponding to the locations of velocity measurements are tentatively estimated from the hard-copy graphs of continuous GRAPE and used for the calculation of impedance. Figure 12 shows the variations of physical properties with depth for Site 586.

As the sediment layer down to the depth of 300 m at Site 586 consists of a single lithologic unit of foraminifer–nannofossil ooze and chalk, variations in physical properties are very small. Variations of compressional wave velocity in the horizontal direction range between 1.55 and 1.63 km/s, and show gradual increase with depth, with a gradient of 1.5%/100 m (Fig. 12). These properties are concordant with those previously obtained at Site 289 (Andrews, Packham, et al., 1975), which is located within 2 km southeast of Site 586.

Values of compressional wave velocity measured under laboratory condition are, however, considerably smaller than those obtained by the Schlumberger Borehole Compensated Velocity Log as shown in Figure 13, in which a fluctuated curve indicates the logging data. Relative differences of core-averaged values indicate nearly linear increase with depth from just below the bottom of the casing to 300 m sub-bottom depth (as shown in Fig. 13 at the right). This discrepancy can be explained

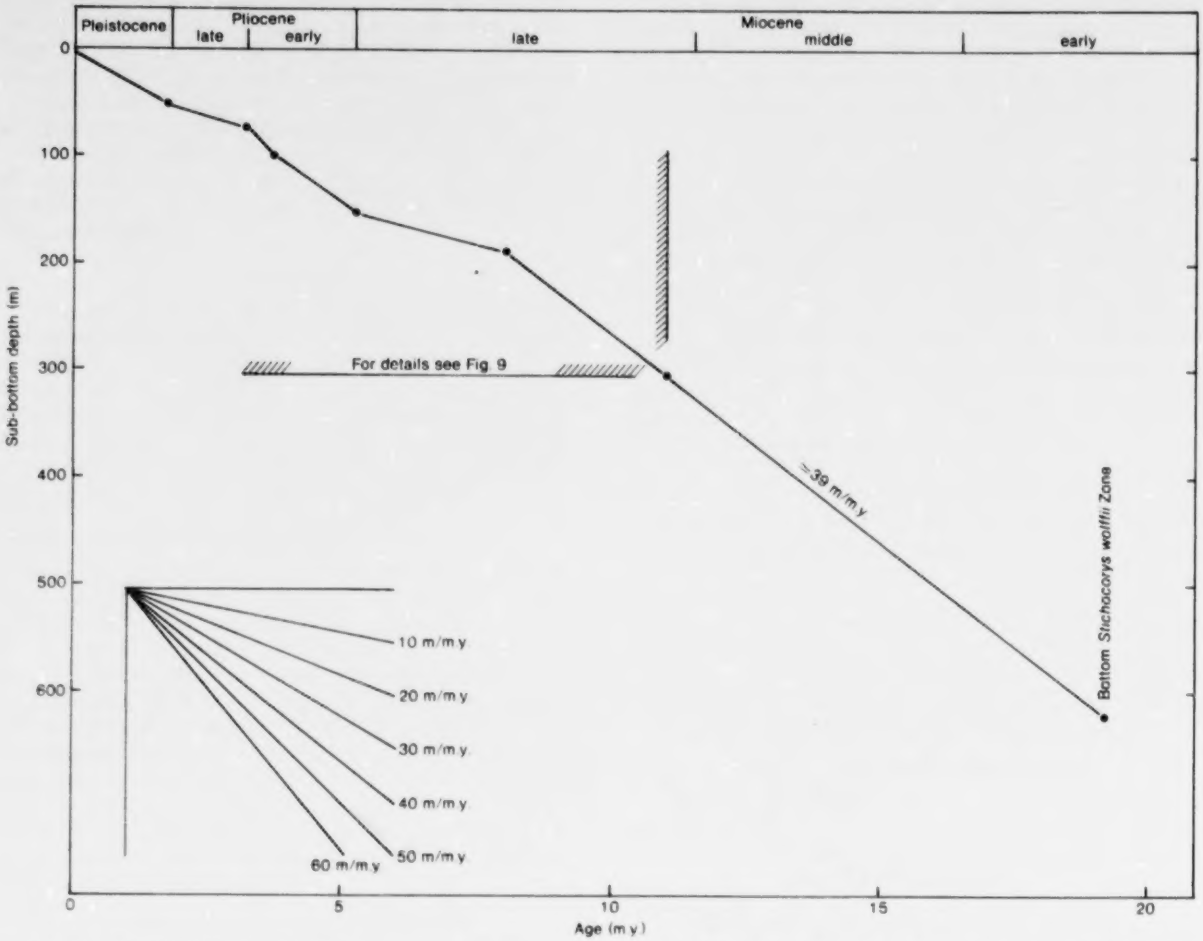


Figure 10. Sedimentation rates of Hole 586C from 300 m sub-bottom to total depth. The upper part is replotted from Figure 9 at a different (larger) scale.

Table 3. Carbonate carbon and organic carbon (C_{org}) data from Site 586.

Sample (interval in cm)	$CaCO_3$ (%)	C_{org} (%)
Hole 586		
1-1, 31-32	84	0.36
5-2, 105-106	89	0.29
Hole 586A		
1-2, 79-80	88	0.29
2-3, 70-71	88	0.24
5-2, 75-76	90	0.28
8-2, 31-32	85	0.62
9-2, 27-28	99	<0.01
12-2, 64-65	96	<0.01
15-2, 60-61	98	0.02
18-2, 60-61	99	0.01
20-2, 82-83	98	0.01
21-4, 108-109	95	0.03
23-5, 82-83	97	<0.01
26-3, 75-76	93	<0.01
28-4, 45-46	99	<0.01
30-1, 54-55	96	<0.01

by porosity rebound, as pointed out by Boyce (1976b), Hamilton (1976), and Shepard et al. (1982).

For unconsolidated sediments, especially those which under laboratory conditions include gas bubbles, the release of pressure causes a considerable increase of porosity and decrease of velocity. The first appearance of tiny bubbles was at a sub-bottom depth of about 150 m after the cores were equilibrated with room temperature. During the velocity measurements, effects of bubbles on the weakening of signal amplitude were noticeable only for the sections indicated by "Gas" in the Remarks column of Table 7. To estimate *in situ* values by using laboratory measurements, it is necessary to know either the amount of dissolved gas components in pore water at depth or volume fractions of gas bubbles under laboratory conditions. It is recommended that a technique be developed to measure physical properties of unconsolidated sediments under bubble-free conditions in the shipboard laboratory.

LOGGING AND DOWNHOLE MEASUREMENTS

Two complete logging runs were made in Hole 586C, covering the interval from the mud line to a total depth

Table 4. Shipboard inorganic chemistry summary, Site 586.

Laboratory sample no.	Sample (interval in cm)	pH	Alkalinity (meq/l)	Salinity (‰)	Calcium (mmol/l)	Magnesium (mmol/l)	Chlorinity (‰)
Surface seawater		7.13	2.97	34.1	10.69	51.38	19.44
Hole 586							
1	2-2, 140-150	7.31	4.10	34.9	11.01	52.79	17.05
Hole 586A							
2	2-5, 140-150	6.83	4.93	34.9	11.10	54.59	20.02
3	7-5, 140-150	7.12	5.432	34.9	11.70	49.40	19.92
4	14-5, 140-150	7.18	5.906	33.6	13.35	47.86	21.67
5	21-5, 140-150	7.10	6.29	34.1	15.08	46.50	19.88
6	28-2, 140-150	7.07	5.804	34.6	15.98	43.17	20.25
IAPSO standard						10.33	52.32
19.24							

Table 5. Titration summary: Ca, Mg, Cl, Site 586.

Sample	A. ml titrant	B. Std. conc.	Factor C-B/A
Calcium	0.525/0.526	10.55 mM/l	20.10
Magnesium	1.125/1.126	64.54 mM/l	57.37
Chlorinity	0.576/0.577	19.375 ‰	

	Calcium		Magnesium			Chlorinity	
Sample (interval in cm)	ml E.G.T.A.	X factor 20.10	ml E.D.T.A.	X factor 57.37	minus Ca	ml $AgNO_3$	X factor 33.70
Surface seawater	0.532	10.69	1.082	62.07	51.38	0.577	19.44
Hole 586							
2-2, 140-150	0.548	11.01	1.112	63.80	52.79	0.506	17.05
Hole 586A							
2-5, 140-150	0.552	11.10	1.145	65.69	54.59	0.594	20.02
7-5, 140-150	0.582	11.70	1.065	61.10	49.40	0.591	19.92
14-5, 140-150	0.664	13.35	1.067	61.21	47.86	0.643	21.67
21-5, 140-150	0.750	15.08	1.089	62.48	46.50	0.590	19.83
28-2, 140-150	0.795	15.98	1.031	59.15	43.17	0.601	20.25
IAPSO	0.514	10.33	1.091	62.65	52.32	0.571	19.24

of 623 m in the hole. Strata at that depth are nannofossil chalks of early Miocene age. The first log run included caliper, gamma ray, resistivity, and sonic velocity; spontaneous potential log (SP) was taken but not printed. The second run included gamma ray, formation density compensated log (FDC), compensated neutron log (CNL), and caliper. A third, a repeat run, was made following the second run. (See Figs. 14 and 15.) Shore-based work in the future will include an impedance log to be made by combining sonic velocity and density logs. From this log a synthetic seismogram will be generated and compared to the air and water gun profiles made during the leg (see Operations section; Schlanger, pers. comm., 1984).

The logs will also be used as comparative material with which to evaluate shipboard velocity and porosity measurements (see section on Physical Properties). Finally when the log data are combined with paleontological data (see Biostratigraphy section) the numerous reflectors seen on seismic profiles across the Ontong-Java Plateau may be realistically interpreted in terms of their nature, origin, and relationship to paleoceanographic events.

SEISMIC STRATIGRAPHY

Seismic profiles that are run across oceanic areas in which thick caps of relatively pure nannofossil- and foraminifer-rich oozes, chalks, and limestones have accumulated generally display numerous, closely spaced reflectors that persist laterally for tens of miles or more. The "signature" and spacing of these reflectors change, of course, with the seismic source and the filter bandpass settings used for recording. The development or expression of these reflectors is particularly marked on oceanic plateaus such as the Ontong-Java Plateau (Fig. 3) and the Magellan Rise, among others. These reflectors

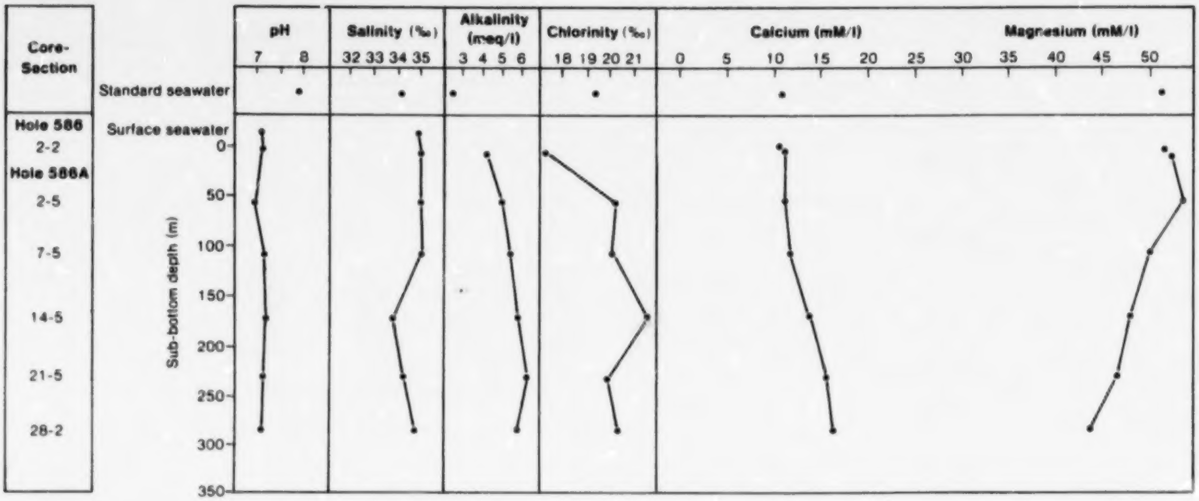


Figure 11. Interstitial water chemistry, Holes 586 and 586A.

Table 6. Locations of the most prominent high-intensity spikes in Hole 586B.

Core-Section (level in cm)	Depth (m)	Intensity (μG)	Core-Section (level in cm)	Depth (m)	Intensity (μG)
3-4, 100	24.70	0.298	4-2, 25	30.55	0.382
4-4, 100	34.30	0.500	5-2, 25	40.15	0.368
7-1, 25	57.85	0.480	8-5, 25	73.45	0.127
11-2, 27	96.67	0.169	14-3, 102	127.72	0.174
15-3, 25	136.55	0.184	16-5, 105	149.95	0.527
17-3, 25	155.75	0.747	17-5, 28	158.78	1.022
19-1, 98	172.68	0.299	21-4, 25	195.65	0.216
22-2, 100	203.00	0.270	22-4, 100	206.00	0.160
23-4, 100	215.60	0.165	23-6, 100	218.60	1.177

have intrigued many stratigraphers since the early legs of the DSDP (Winterer, Riedel, et al., 1971; Moberly and Heath, 1971).

Drilling at such DSDP sites as 64, 288, and 289 on the Ontong-Java Plateau produced an enormous amount of physical properties data which, when combined with paleontological and, in some cases, drilling rate data, resulted in attempts to date and explain the origin of the reflectors (e.g., van der Lingen and Packham, 1975). It had become clear by the middle 1970s that, although the source of the reflectors lay in subtle acoustic impedance differences between carbonate layers, it was not obvious if these impedance differences were due to some combination of sedimentation rate changes, variations in microfossil content, and diagenetic effects. If a section of pure carbonate of invariant texture simply underwent compaction, no marked impedance differences would develop in the column and so there would be no reflectors. One problem that arose early in the interpretation of the origin of the reflectors was derived from the fact that the acoustic velocities and density values measured aboard ship showed very little variation downhole, particularly in the upper several hundreds of meters.

The discovery, by drilling, that chalk layers could be interbedded with relatively uncemented oozes led to the idea that cementation within these carbonate columns was not strictly depth-dependent but might be a function of the original composition of the layers, which, in turn, might be a function of paleoceanographic conditions. Schlanger and Douglas (1974) applied these ideas to the development of a model for the carbonate ooze-chalk-limestone transition and related certain reflectors to paleoceanographic events such as glaciations.

All of this history is built into the interpretation of the seismic stratigraphy of the Site 289 area shown on Figure 3. What is new about this version is that logging was carried out to a depth of 623 m in Hole 586C (see sections on Physical Properties, Logging and Downhole Measurements). The sonic velocity log showed that *in situ* velocities are considerably higher than those measured aboard ship. A preliminary impedance log showed significant vertical variation.

The interpretation shown on Figure 3 is based on:

1. The sonic velocity, formation density, and compensated neutron logs.
2. Data from the drilling of Site 289 on Leg 30.
3. Paleontological data from Site 289.
4. Paleontological and sedimentation rate data from Leg 89.

This interpretation is provisional and it is planned to revise it after the logs run in the hole are processed ashore, at which time a refined impedance log will be provided as well as a reflection coefficient log; these could then be used to produce synthetic seismograms which, it is hoped, would eliminate most acoustic artifacts (Schlanger, pers. comm., 1984).

SUMMARY AND CONCLUSIONS

Holes 586, 586A, and 586C

Site 586 was planned by the JOIDES Ocean Paleoenvironment Panel essentially as a redrilling, by use of the hydraulic piston corer, of the upper section of DSDP Site 289, which was originally drilled on Leg 30 to a

Table 7A. Physical properties of sediments, Site 586: Porosity, wet-bulk density, water content, and grain density.

Sample (level in cm)	Sub-bottom depth (m)	Porosity (%)	Wet-bulk density[a] (g/cm³)	Water content (%)	Grain density (g/cm³)
Hole 586					
2-1, 60	6.0	66.0	1.47	44.8	2.39
2-3, 75	9.2	48.6	1.49	32.6	1.95
2-5, 75	12.2	64.4	1.47	43.7	2.34
4-1, 72	26.1	68.0	1.56	43.5	2.76
4-3, 75	29.2	60.0	1.55	38.6	2.38
4-5, 75	32.2	63.0	1.59	39.7	2.59
5-1, 70	35.6	66.1	1.60	41.4	2.76
5-3, 71	38.6	63.5	1.54	41.2	2.49
5-5, 75	41.7	67.9	1.58	43.0	2.81
Hole 586A					
1-1, 71	45.1	58	1.48	39	2.16
1-3, 71	48.1	54	1.34	40	1.73
1-5, 71	51.1	64	1.53	42	2.49
2-1, 71	54.7	63	1.49	43	2.30
2-3, 71	57.7	57	1.60	36	2.39
2-5, 71	60.7	62	1.66	38	2.70
3-3, 75	67.4	63	1.54	41	2.45
3-5, 75	70.4	64	1.56	41	2.53
4-1, 70	73.9	68	1.56	44	2.71
4-3, 70	76.9	69	1.55	45	2.74
4-5, 70	79.9	61	1.51	41	2.28
5-1, 70	83.5	68	1.58	43	2.78
5-3, 70	86.5	62	1.56	40	2.50
5-5, 70	89.5	70	1.61	44	2.99
6-2, 70	94.6	72	1.63	44	3.25
6-4, 70	97.6	68	1.56	43	2.78
6-6, 70	100.6	64	1.64	39	2.68
7-1, 70	102.7	67	1.65	40	3.00
7-3, 70	105.7	62	1.50	41	2.37
7-5, 70	108.7	65	1.61	40	2.75
8-1, 70	112.3	64	1.60	40	2.65
8-3, 70	115.7	64	1.58	41	2.58
8-5, 70	118.3	65	1.62	40	2.79
9-1, 70	121.9	87	1.71	51	1.49
9-3, 70	124.9	31	1.28	24	1.41
9-6, 70	127.9	58	1.40	41	1.95
10-1, 70	131.5	55	1.62	34	2.39
10-3, 70	134.5	58	1.55	37	2.32
10-5, 70	137.5	61	1.62	38	2.59
11-1, 70	141.1	59	1.51	39	2.21
11-3, 70	144.1	62	1.57	40	2.48
11-5, 70	147.1	58	1.51	38	2.22
12-1, 70	150.7	57	1.46	39	2.06
12-3, 70	153.7	50	1.29	39	1.57
12-5, 70	156.7	62	1.71	36	2.85
13-1, 70	160.3	47	1.25	38	1.45
13-3, 70	163.3	65	1.59	41	2.72
13-5, 70	166.3	61	1.51	40	2.31
14-1, 70	167.6	47	1.25	38	1.45
14-3, 70	170.6	63	1.62	39	2.64
15-1, 70	182.5	59	1.65	36	2.58
15-3, 70	175.5	63	1.65	39	2.71
15-5, 70	178.5	51	1.45	35	1.89
16-1, 70	181.5	63	1.66	38	2.77
16-3, 70	184.5	56	1.57	36	2.30
16-5, 70	187.5	70	1.64	43	3.11
17-1, 70	191.1	61	1.67	36	2.70
17-3, 70	194.1	71	1.78	40	3.74
17-5, 70	197.1	54	1.46	37	1.97
18-1, 70	200.7	54	1.56	34	2.24
18-3, 70	203.7	62	1.69	37	2.81
18-5, 70	206.7	53	1.57	34	2.21
19-1, 70	210.3	67	1.75	38	3.31
19-3, 70	213.3	58	1.64	35	2.53
19-5, 70	216.3	53	1.54	34	2.17
20-1, 70	218.8	51	1.52	34	2.03
20-3, 70	221.8	59	1.54	38	2.59
20-5, 70	224.8	48	1.32	36	1.63
21-3, 71	228.4	57	1.62	35	2.46
21-5, 70	231.4	52	1.55	34	2.15
21-7, 70	234.4	66	1.58	42	2.72
22-1, 70	238.0	58	1.66	35	2.61
22-3, 70	241.0	56	1.61	35	2.40
22-5, 70	244.0	55	1.52	36	2.15
23-1, 70	247.6	56	1.52	37	2.17
23-3, 70	250.6	57	1.61	35	2.43
23-5, 70	253.6	58	1.64	35	2.53
24-1, 70	257.2	55	1.62	34	2.36
24-3, 70	260.2	58	1.58	37	2.38
24-5, 70	263.2	58	1.65	35	2.54
25-1, 70	266.8	57	1.62	35	2.44
25-3, 70	269.8	56	1.50	38	2.12
25-5, 70	272.8	58	1.63	36	2.51
26-1, 71	276.4	48	1.61	30	2.17
26-2, 71	277.9	72	1.57	46	3.04
26-3, 71	279.4	34	1.24	27	1.37
27-1, 71	282.4	62	1.62	38	2.65
27-3, 71	285.4	59	1.50	39	2.21
28-3, 71	289.6	55	1.56	35	2.22
29-1, 71	291.0	49	1.38	36	1.72
29-3, 71	294.0	53	1.49	36	2.04
30-1, 71	296.0	54	1.48	37	2.02
30-3, 71	299.0	54	1.56	34	2.24
31-1, 71	301.0	52	1.48	35	2.00
31-3, 71	304.0	52	1.56	33	2.17

Note: Sub-bottom depths are based opon original shipboard calculations and may be in error by 5.1 m.

[a] Measured by the gravimetric method.

Table 7B. Physical properties of sediments, Site 586: Compressional wave velocity, wet-bulk density, and impedance.

Sample (level in cm)	Sub-bottom depth (m)	Compressional-wave velocity (km/s)	Wet-bulk density[a] (g/cm³)	Impedance[b] (10^5 g/cm² s)	Remarks[c]
Hole 586A					
22-5, 50	243.8	1.62			
22-5, 100	244.3	1.62			
22-6, 50	245.3	1.63			
22-6, 100	246.3	1.62			
23-1, 50	247.3	1.60			
23-1, 100	247.9	1.61			
23-2, 50	248.9	1.61	1.77	2.85	
23-2, 100	249.4	1.62	1.75	2.84	
23-3, 50	250.4	1.60			Gas
23-3, 100	250.9	1.59			Gas
23-4, 50	251.9	1.60	1.76	2.82	
23-4, 100	252.4	1.59	1.76	2.80	
23-5, 50	253.4	1.61			
23-5, 100	253.9	1.60			
23-6, 50	254.9	1.60	1.77	2.83	
23-6, 100	255.4	1.61	1.77	2.85	
24-1, 50	257.0	1.60			
24-1, 100	257.5	1.61			
24-2, 50	258.5	1.60	1.75	2.80	
24-2, 100	259.0	1.58	1.75	2.77	
24-3, 50	260.0	1.58			
24-3, 100	260.5	1.58			
24-4, 50	261.5	1.58	1.73	2.73	
24-4, 100	262.5	1.59	1.73	2.75	
24-5, 50	262.5	1.58			
24-5, 100	263.0	1.59			
24-6, 50	264.0	1.59			
24-6, 100	264.5	1.61			
25-1, 50	266.6	1.61			
25-1, 100	267.1	1.60			
25-2, 50	268.1	1.61	1.76	2.83	
25-2, 100	268.6	1.59	1.76	2.80	
25-3, 50	269.6	1.59			
25-3, 100	270.1	1.60			
25-4, 50	271.1	1.60	1.72	2.75	
25-4, 100	271.6	1.60	1.73	2.77	
25-5, 50	272.6	1.61			
25-6, 100	273.1	1.61			
25-6, 50	274.1	1.61			
25-6, 100	274.6	1.63			
26-1, 50	276.2	1.62			
26-1, 100	276.7	1.62			
26-2, 50	277.7	1.63	1.80	2.93	
26-2, 100	278.2	1.64	1.77	2.90	
26-3, 50	279.2	1.66			
27-1, 50	282.2	1.62			Gas
27-1, 100	282.7	1.60			Gas
27-2, 50	283.7	1.61	1.74	2.80	Gas
27-3, 100	284.2	1.60	1.74	2.78	Gas
27-3, 50	285.2	1.58			Gas
28-2, 50	286.6	1.60			
28-2, 100	287.1	1.60			
28-3, 50	287.9	1.60	1.73	2.77	
28-3, 100	288.4	1.61	1.73	2.79	
28-4, 50	289.4	1.62			
29-1, 50	290.8	1.60			
29-1, 100	291.3	1.61			Gas
2-2, 50	292.3	1.59	1.77	2.81	Gas
2-2, 100	292.8	1.59	1.75	2.78	Gas
2-3, 50	293.8	1.62			Gas
2-3, 100	294.3	1.61			
30-1, 50	295.8	1.61			
30-1, 100	296.3	1.61			
30-2, 50	297.3	1.62	1.75	2.84	
30-2, 100	297.8	1.62	1.73	2.80	
30-3, 50	298.8	1.61			
30-3, 100	299.3	1.62			
31-1, 50	300.0	1.60			
31-1, 100	301.3	1.59	1.73	2.75	
31-2, 50	302.3	1.60	1.76	2.82	
31-2, 100	302.8	1.60	1.78	2.85	
31-3, 50	303.8	1.60	1.75	2.80	
31-3, 100	304.3	1.60	1.77	2.83	
Hole 586B					
1-4, 50	10.1	1.55	1.60	2.48	
1-4, 100	10.6	1.56	1.62	2.53	
2-4, 50	16.0	1.58	1.62	2.56	
2-4, 100	16.5	1.56	1.62	2.53	
3-4, 50	25.6	1.59	1.65*	2.62	
3-4, 100	27.1	1.56	1.65*	2.57	
4-4, 50	35.2	1.57	1.63	2.56	

Table 7B. (Continued).

Sample (level in cm)	Sub-bottom depth (m)	Compressional-wave velocity (km/s)	Wet-bulk density[a] (g/cm^3)	Impedance[b] (10^5 g/cm^2 s)	Remarks[c]
Hole 586B (Cont.)					
4-4, 100	35.7	1.56	1.65	2.57	
5-4, 50	44.8	1.54	1.65	2.54	
5-4, 100	45.3	1.57	1.63	2.56	
6-4, 50	54.4	1.56	1.67	2.61	
6-4, 100	54.9	1.60	1.63	2.67	
7-4, 50	64.0	1.55	1.65*	2.56	
7-4, 100	64.5	1.53	1.65*	2.52	
8-4, 50	73.6	1.58	1.65*	2.61	
8-4, 100	74.1	1.57	1.65*	2.59	
9-4, 50	83.2	1.55	1.60	2.48	
9-4, 100	83.7	1.56	1.63	2.54	
10-4, 50	92.8	1.58	1.67	2.64	
10-4, 100	93.3	1.58	1.68	2.65	
11-4, 50	101.3	1.57	1.69	2.65	
11-4, 100	101.8	1.57	1.70	2.67	
12-4, 50	110.9	1.57	1.70	2.67	
12-4, 100	111.4	1.58	1.70	2.69	
13-4, 50	120.5	1.59	1.74	2.77	
13-4, 100	121.0	1.56	1.74	2.71	
14-4, 50	130.1	1.57	1.68	2.64	
14-4, 100	130.6	1.57	1.70	2.67	
15-4, 50	139.7	1.59	1.68	2.67	
15-4, 100	140.2	1.56	1.65	2.57	
16-4, 50	149.3	1.58	1.73	2.73	
16-4, 100	149.8	1.58	1.74	2.75	
17-4, 50	158.9	1.61	1.72	2.77	
17-4, 100	159.4	1.58	1.68	2.65	
18-4, 50	168.4	1.58	1.71	2.70	
18-4, 100	169.0	1.57	1.70	2.67	
19-4, 50	178.1	1.59	1.72	2.73	
19-4, 100	178.6	1.58	1.72	2.72	
20-4, 50	187.7	1.60	1.71	2.74	Gas
20-4, 100	188.2	1.61	1.70	2.74	
21-4, 50	197.3	1.60	1.70	2.72	Gas
21-4, 100	197.8	1.59	1.72	2.73	Gas
22-4, 50	206.9	1.62	1.75	2.84	Gas
22-4, 100	207.4	1.62	1.73	2.80	Gas
23-4, 50	216.5	1.60	1.70	2.72	Gas
23-4, 100	217.0	1.59	1.72	2.73	Gas
24-4, 50	226.1	1.58	1.73	2.73	
24-4, 100	226.6	1.60	1.75	2.80	
25-4, 50	235.7	1.60	1.76	2.82	
25-4, 100	236.2	1.61	1.78	2.87	

Note: Sub-bottom depths are based upon original shipboard calculations and may be in error by 5.1 m.

[a] Measured by continuous GRAPE.

[b] Calculated from wet-bulk density measured by continuous GRAPE.

[c] "Gas" indicates the noticeable weakening of acoustic signals by gas bubbles.

depth of 1262.5 m, bottoming in Aptian limestones underlain by basalt. Details of the original results can be referred to in Andrews, Packham, et al. (1975). The purpose of reoccupying Site 289 was to obtain a detailed Neogene sediment record to understand better the paleoceanographic history on an equatorial shallow-water rise which had accumulated almost pure foraminiferal and nannofossil carbonates at high sedimentation rates. Site 586 is the northernmost of a series of HPC sites, the rest of which were drilled on Leg 90 in the southwest Pacific.

Four holes were drilled at Site 586; Hole 586 ended when a core barrel sub broke at 39.3 m depth; Hole 586A was continuously cored between 39.3 and 300.2 m; Hole 586B penetrated to 240.3 m sub-bottom. The entire section consists of foraminiferal and nannofossil ooze which became chalky at a depth of approximately 260 m. In Hole 586A the oldest sediments cored are of late Miocene age in the N16 foraminifer Zone, the CN7 nannofossil Zone, and the *C. pettersoni* radiolarian Zone. A fourth hole, 586C, was washed to a depth of 613.5 m and a single core was taken at 613.5–623.1 m in the *S. wolffii* radiolarian Zone of early Miocene age. The purpose of this hole was to create an opportunity to log the pure carbonate section known to exist from Leg 30 data so as to acquire logs which would enable us to (1) compare shipboard physical properties data with *in situ* data on sonic velocities, densities, and impedance contrasts and (2) be better able to interpret the seismic stratigraphy of the Ontong-Java Plateau. To these ends the logging program was successful. Sonic velocities measured in the hole are significantly higher than shipboard measurements. These data combined with paleontological data allowed a new reinterpretation of the seismic reflectors (see section on Seismic Stratigraphy).

The paleontological studies of the Leg 89 group indicate that the carbonate section on the Ontong-Java Plateau is not the product of a purely pelagic "rain," but that the sediments probably contain allochthonous elements, as discussed later.

As shown by the foraminifer record, the sediments, which at first sight appear to display the sedimentological characteristics of a foraminifer–nannofossil ooze, were affected by mechanical transport, that caused (1) an accumulation of foraminiferal tests within the range of the sand fraction and (2) an admixture of forms from different environments, ranging from shallow-water platforms to bathyal depths. Thus, the sediments encountered at this site are more properly defined as a graded foraminifer–nannofossil silty sand.

Both planktonic and benthic foraminifers from the same sample show different preservation, the same species occurring with both transparent and chalky tests. It is not clear if the best preserved tests are autochthonous or allochthonous.

In addition, each residue contains specimens of *Quinqueloculina*, coarse agglutinated foraminifers, large nodosariids (one chamber was over 2 mm in size), and highly ornamented ostracodes indicative of an environment much shallower than the present water depth at Site 586, 2208 m (below sea level), or than the estimated bathyal paleodepth based on the supposed autochthonous benthic foraminifers. It is worth mentioning that evidence of obvious reworking could not be detected in this preliminary study, although it cannot be ruled out.

There is a large variation in the size of the radiolarian microfauna. The size fraction greater than 150 µm is large in some samples and small in others. For example, in 586A-8,CC less than 1% of the assemblage is greater than 150 µm. A high percentage of small tests can be interpreted to result from an allochthonous, transported fauna; a high percentage of large tests indicates an autochthonous fauna.

Sedimentation ratios at the site varied considerably through time from a low of 13 m/m.y. in late Miocene time to a high of 54 m/m.y. in mid-Pliocene time, 3 to 4 m.y. ago.

Hole 586B (by Leg 90 shipboard scientific party)

The Leg 90 scientific team split, described, and dated the sequence at Hole 586B (Ontong-Java Plateau) collected during Leg 89, with 98% recovery. This appears to be a continuous, uncomplicated section from Quater-

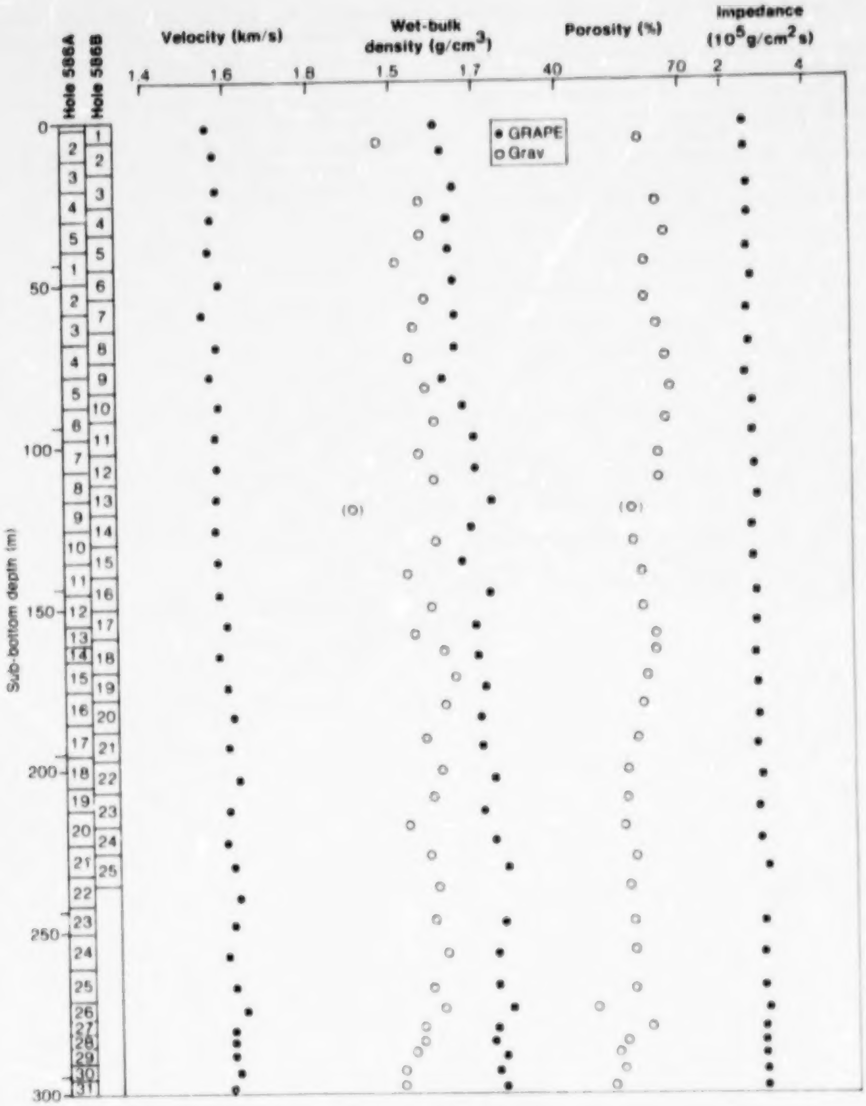


Figure 12. Variations of physical properties with depth at Site 586.

nary to early late Miocene age. Cores are generally of good quality except for severe disturbance within five of the cores. Hole 586B differs only in details from descriptions of Holes 586 and 586A. All major calcareous and siliceous microfossil groups are represented. The section is from one lithostratigraphic unit, composed of foraminifer-bearing to foraminifer-nannofossil ooze. The sequence is intensely bioturbated, with numerous sedimentary features related to bioturbation. The upper 45 m of the section is marked by numerous thin, foraminifer-rich zones that apparently resulted from winnowing. Unlike the report for Hole 586, there is little evidence of extensive reworking or turbidite layers.

REFERENCES

Andrews, J. E., Packham, G. H., et al., 1975. *Init. Repts. DSDP*, 30: Washington (U.S. Govt. Printing Office).

Berggren, W. A., 1977. Late Neogene planktonic foraminiferal biostratigraphy of DSDP Site 357 (Rio Grande Rise). *In* Supko, P. R., Perch-Nielsen, K., et al., *Init. Repts. DSDP*, 39: Washington (U.S. Govt. Printing Office), 591-614.

Blow, W. H., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proc. 1st Int. Conf. Planktonic Microfossils* (Vol. 1): Leiden (E. J. Brill), 199-422.

Boyce, R. E., 1976a. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

________, 1976b. Sound velocity-density parameters of sediment and rock from DSDP Sites 315-318 on the Line Islands Chain, Manihiki Plateau, and Tuamotu Ridge in the Pacific Ocean. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Ellis, C. H., 1982. Calcareous nannoplankton biostratigraphy—Deep Sea Drilling Project Leg 60. *In* Hussong, D. M., Uyeda, S., et al., *Init. Repts. DSDP*, 60: Washington (U.S. Govt. Printing Office), 507–536.

Gartner, S., 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Mar. Micropaleontol.*, 2:1–25.

Hamilton, E. L., 1976. Variations of density and porosity with depth in deep-sea sediments. *J. Sed. Petrol.*, 46:280–300.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific.* IMR Technical Reports, Scripps Institution of Oceanography, La Jolla, California.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proc. II Planktonic Conf., Roma:* Rome (Ed. Tecnoscienza), pp. 739–785.

Milholland, P., Manghnani, M. H., Schlanger, S. O., and Sutton, G. H., 1980. Geoacoustic modelling of deep-sea carbonate sediments. *J. Acoust. Soc. Am.*, 68:1351–1360.

Moberly, R., and Heath, G. R., 1971. Carbonate sedimentary rocks from the western Pacific: Leg 7, Deep Sea Drilling Project. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7, Pt. 2: Washington (U.S. Govt. Printing Office), 977–986.

Moberly, R., Schlanger, S. O., et al., in press. *Init. Repts. DSDP*, 89: Washington (U.S. Govt. Printing Office).

Nigrini, C., 1971. Radiolarian zones in the Quaternary of the equatorial Pacific Ocean. *In* Funnell, B. M., and Riedel, W. R. (Eds.), *The Micropaleontology of the Oceans:* London (Cambridge Univ. Press), pp. 443–461.

Okada, H., and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Mar. Micropaleontol.*, 5: 321–325.

Riedel, W. R., and Sanfilippo, A., 1978. Stratigraphy and evolution of tropical Cenozoic radiolarians. *Micropaleontology*, 23(1):61–96.

Schlanger, S. O., and Douglas R. G., 1974. The pelagic ooze-chalk transition and its implications for marine stratigraphy. *In* Hsü, K. J., and Jenkyns, H. (Eds.), *Pelagic Sediments on Land and under the Sea.* Int. Assoc. Sed. Spec. Publ., 1:117–148.

Shepard, L. E., Bryant, W. R., and Chiou, W. A., 1982. Geotechnical properties of Middle America Trench sediments, Deep Sea Drilling Project, Leg 66. *In* Watkins, J. S., Moore, J. C., et al., *Init. Repts. DSDP*, 66: Washington (U.S. Govt. Printing Office), 475–504.

Srinivasan, M. S., and Kennett, J., 1981. Neogene planktonic foraminiferal biostratigraphy and evolution: Equatorial to subantarctic, South Pacific. *Mar. Micropaleontol.*, 6:499–533.

van der Lingen, G. J., and Packham, G., 1975. Relationships between diagenesis and physical properties of biogenic sediments of the Ontong-Java Plateau (Sites 288 and 289, Deep Sea Drilling Project). *In* Andrews, J. E., Packham, G., et al., *Init. Repts. DSDP*, 30: Washington (U.S. Govt. Printing Office), 443–482.

Vincent, E., 1981. Neogene planktonic foraminifers from the central North Pacific, Deep Sea Drilling Project Leg 62. *In* Thiede, J., Vallier, T. L., et al., *Init. Repts. DSDP*, 62: Washington (U.S. Govt. Printing Office), 329–353.

Winterer, E. L., and Riedel, W. R., et al., 1971. *Init. Repts. DSDP*, 7: Washington (U.S. Govt. Printing Office).

Date of Acceptance: 12 January 1983

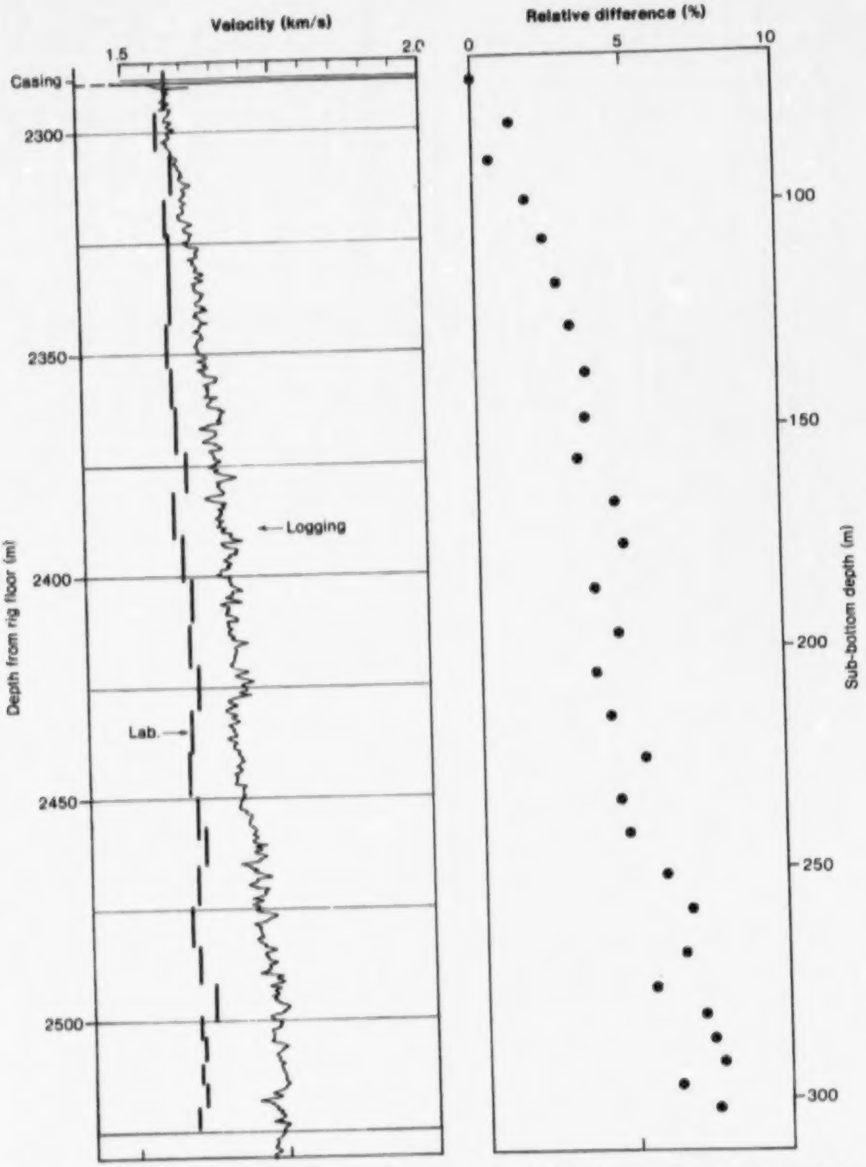


Figure 13. Variations of compressional wave velocities from shipboard measurements and velocity logs with depth at Site 586. Relative differences between these as a function of depth are shown at the right.

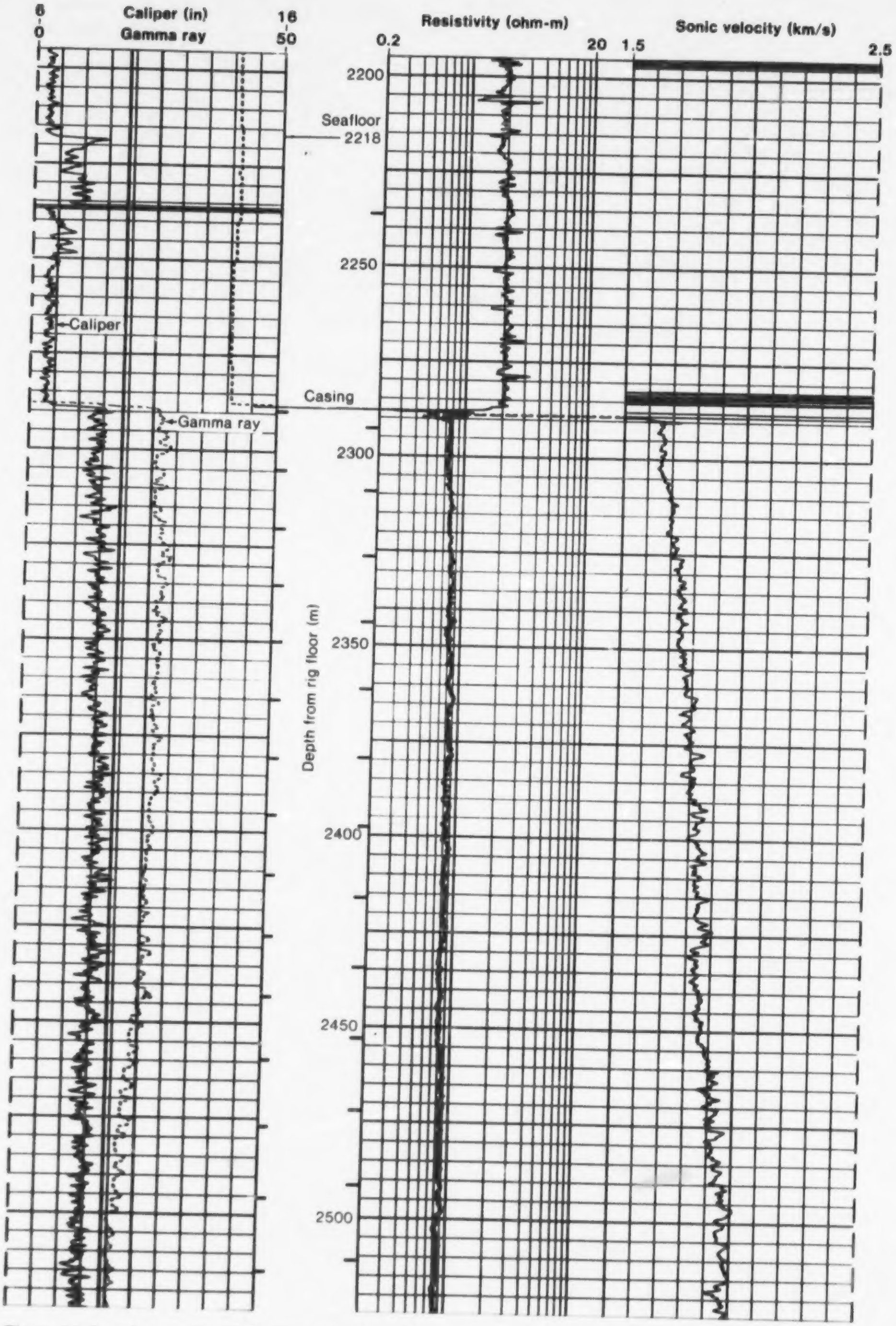


Figure 14. Logging results, Hole 586C, showing caliper, gamma-ray, resistivity, and sonic velocity.

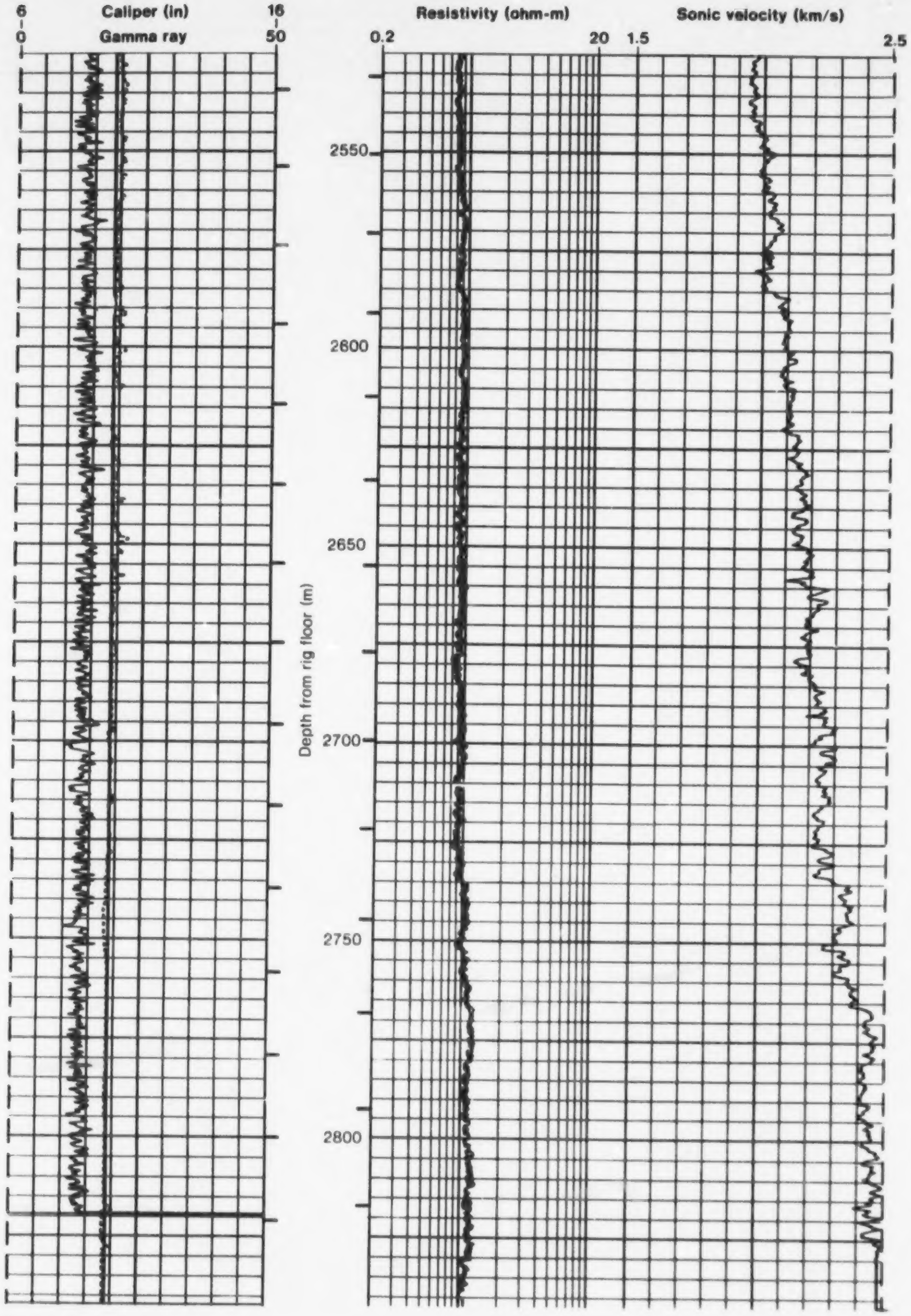


Figure 14. (Continued).

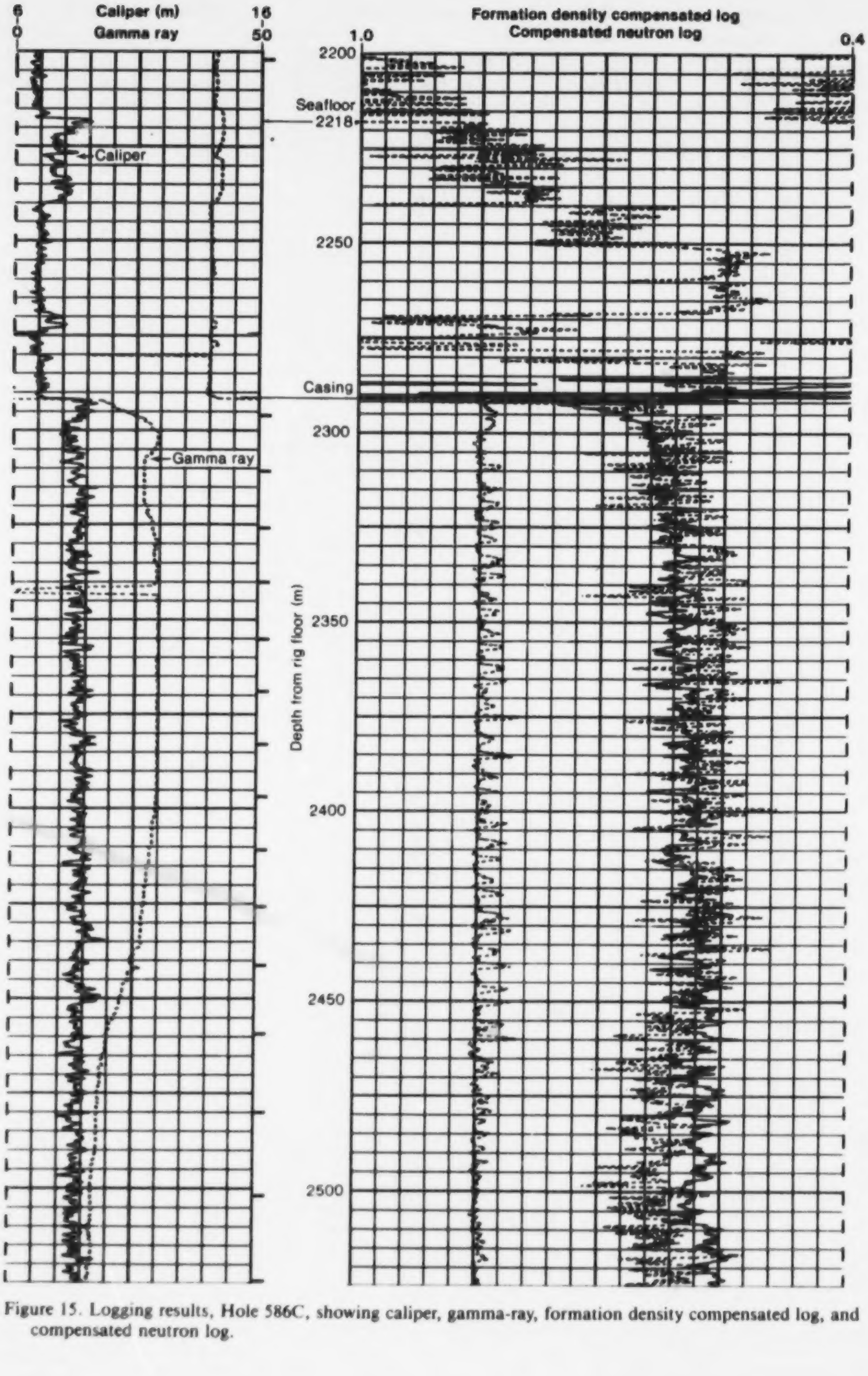


Figure 15. Logging results, Hole 586C, showing caliper, gamma-ray, formation density compensated log, and compensated neutron log.

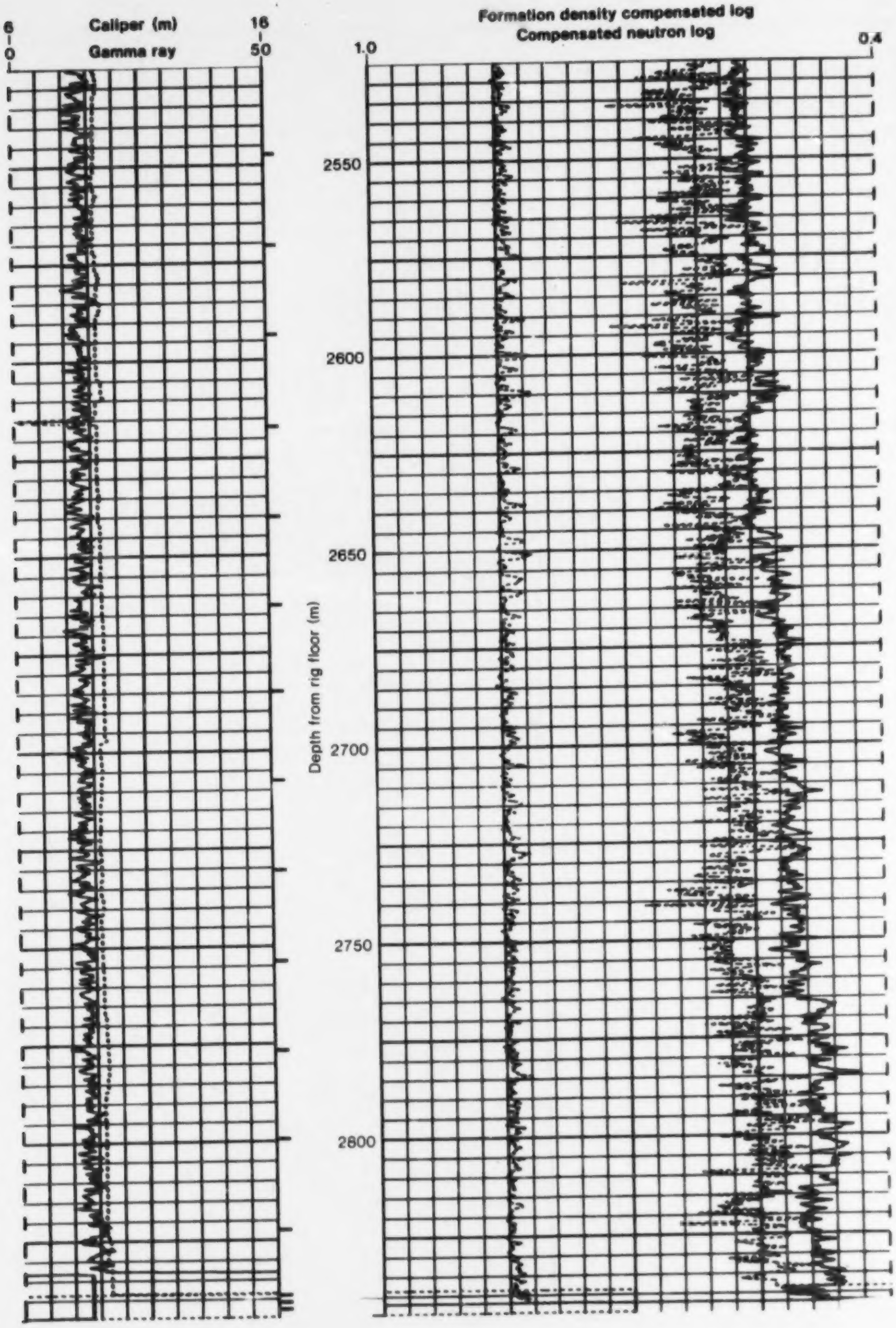
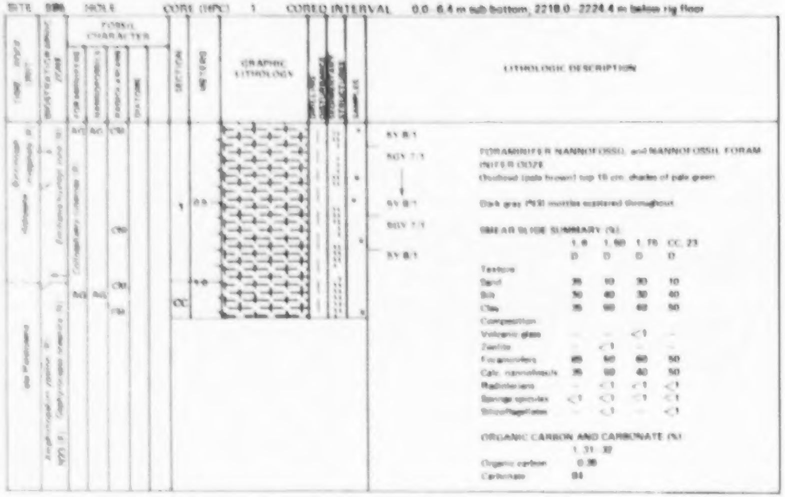


Figure 15. (Continued).

SITE 586 HOLE CORE (HPC) 1 CORED INTERVAL 0.0–6.4 m sub bottom, 2218.0–2224.4 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
AG AG CM
CM
AG AG CM
FM
1
0.5
CC
5Y 8/1
5GY 7/1
5Y 8/1
5GY 7/1
5Y 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL and NANNOFOSSIL FORAMINIFER OOZE

Oxidized (pale brown) top 10 cm; shades of pale green

Dark gray (N3) mottles scattered throughout

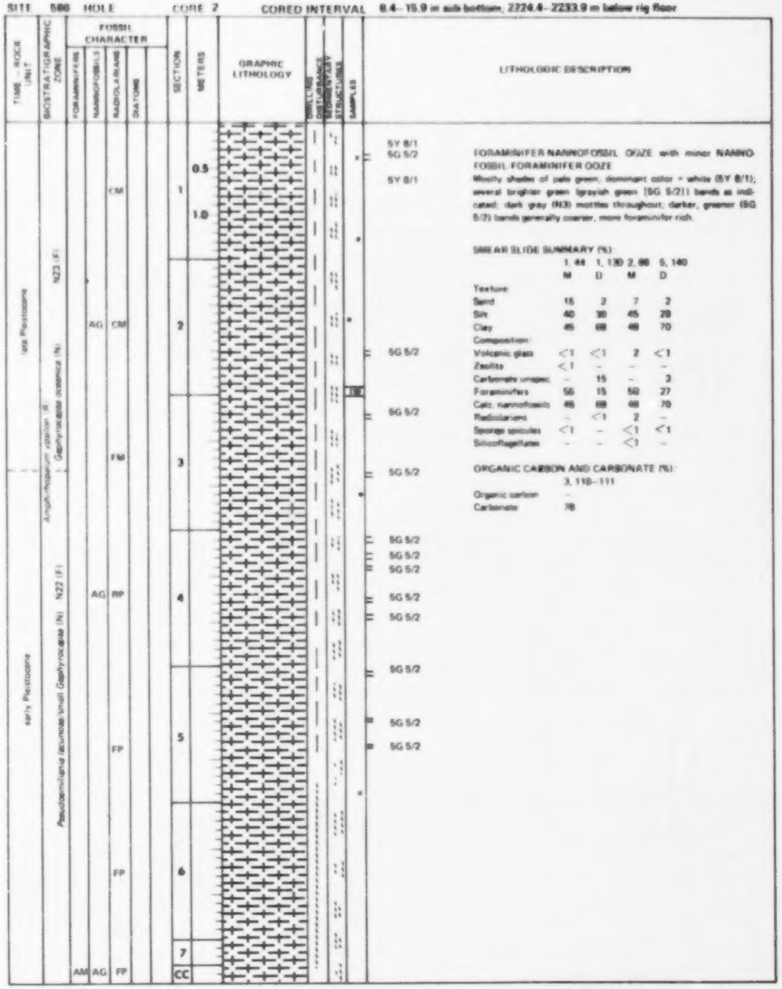
SMEAR SLIDE SUMMARY (%):

	1, 8 D	1, 50 D	1, 78 D	CC, 23 D
Texture:				
Sand	35	10	30	10
Silt	30	40	30	40
Clay	35	50	40	50
Composition:				
Volcanic glass	–	–	<1	–
Zeolite	–	<1	–	–
Foraminifers	65	50	60	50
Calc. nannofossils	35	50	40	50
Radiolarians	–	<1	<1	<1
Sponge spicules	<1	<1	<1	<1
Silicoflagellates	–	<1	–	<1

ORGANIC CARBON AND CARBONATE (%):

	1, 31–32
Organic carbon	0.38
Carbonate	84

SITE 586 HOLE CORE 2 CORED INTERVAL 6.4–15.9 m sub bottom, 2224.4–2233.9 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pleistocene
early Pleistocene
N23 (F)
Gephyrocapsa oceanica (N)
Amphirhopalum ypsilon (R)
N22 (F)
Pseudoemiliania lacunosa/small Gephyrocapsa (N)
CM
AG CM
FM
AG RP
FP
FP
AM AG FP
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
5G 5/2
5Y 8/1
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2

LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE with minor NANNOFOSSIL FORAMINIFER OOZE

Mostly shades of pale green, dominant color = white (5Y 8/1); several brighter green (grayish green [5G 5/2]) bands as indicated; dark gray (N3) mottles throughout; darker, greener (5G 5/2) bands generally coarser, more foraminifer rich.

SMEAR SLIDE SUMMARY (%):

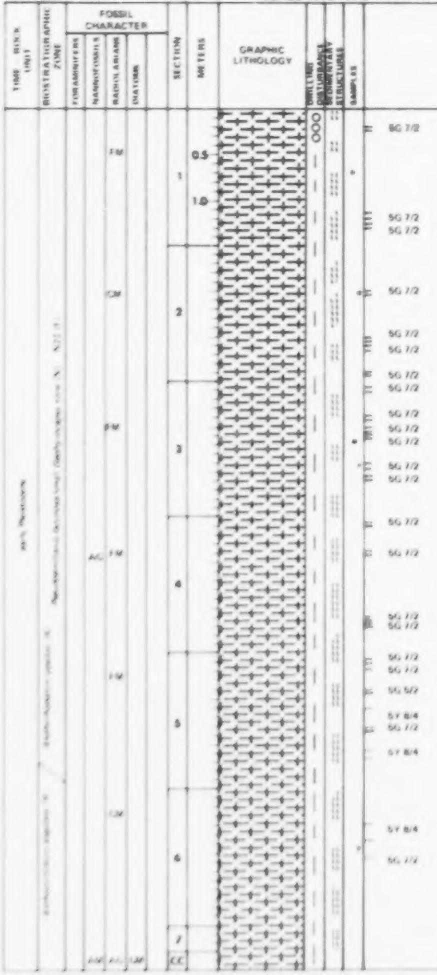
	1, 44 M	1, 130 D	2, 86 M	5, 140 D
Texture:				
Sand	15	2	7	2
Silt	40	30	45	28
Clay	45	68	48	70
Composition:				
Volcanic glass	<1	<1	2	<1
Zeolite	<1	–	–	–
Carbonate unspec.	–	15	–	3
Foraminifers	56	15	50	27
Calc. nannofossils	45	68	48	70
Radiolarians	–	<1	2	–
Sponge spicules	<1	–	<1	<1
Silicoflagellates	–	–	<1	–

ORGANIC CARBON AND CARBONATE (%):

	3, 110–111
Organic carbon	–
Carbonate	78

Information on core description sheets, for ALL sites, represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.

SITE 586 HOLE CORE 3 CORED INTERVAL 15.9–25.4 m sub-bottom; 2233.9–2243.4 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
Pseudoemiliania lacunosa (small Gephyrocapsa) zone (N)
N22 (F)
Anthocyrtidium angulare (R)
FM
CM
FM
AG
FM
FM
CM
AM
AG
CM
0.5
1.0
1
2
3
4
5
6
7
CC
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 5/2
5Y 8/4
5G 7/2
5Y 8/4
5Y 8/4
5G 7/2

LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE with minor NANNOFOSSIL FORAMINIFER OOZE

Dominant color is white (5Y 8/1) with faint, coarser greener layers (pale green (5G 7/2)) as indicated and minor layers and mottles of yellow gray (5Y 7/2) and grayish yellow (5Y 8/4) which also are coarser than the dominant white (5Y 8/1).

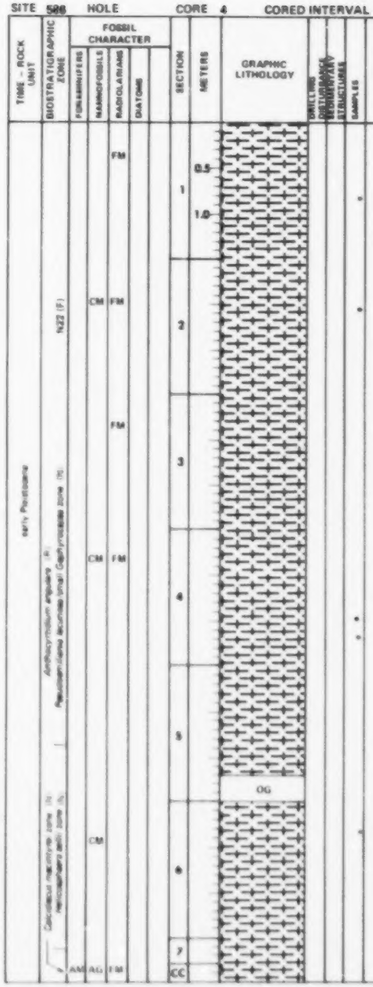
SMEAR SLIDE SUMMARY (%)

	1, 70	2, 61	3, 81	6, 57
	D	M	M	M
Texture				
Sand	5	15	10	12
Silt	35	35	25	16
Clay	60	50	65	83
Composition				
Volcanic glass	1	<1	1	–
Pyrite	–	–	–	12
Carbonate unspec.	2	10	5	–
Foraminifers	35	40	25	5
Calc. nannofossils	60	50	65	83
Radiolarians	2	<1	1	<1
Sponge spicules	<1	<1	–	<1

ORGANIC CARBON AND CARBONATE (%)

	3, 76–77
Organic carbon	–
Carbonate	86

SITE 586 HOLE CORE 4 CORED INTERVAL 25.4–34.9 m sub-bottom; 2243.4–2252.0 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
Anthocyrtidium angulare (R)
Pseudoemiliania lacunosa (small Gephyrocapsa) zone (N)
N22 (F)
Calcidiscus macintyrei zone (N)
Helicosphaera sellii zone (N)
FM
CM
FM
FM
CM
FM
CM
AM
AG
FM
0.5
1.0
1
2
3
4
5
6
7
CC
OG

LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) with mottles of pale yellow (5Y 8/3); thin beds (<1 cm) of pale green (5G 7/2) occur throughout; many are very faint and appear mainly as greener tinges; 5G 7/2 and 5Y 7/3 layers and mottles are somewhat coarser; blebs and small mottles (mostly <1 cm) of dark gray (N3) pyrite-bearing material are common throughout.

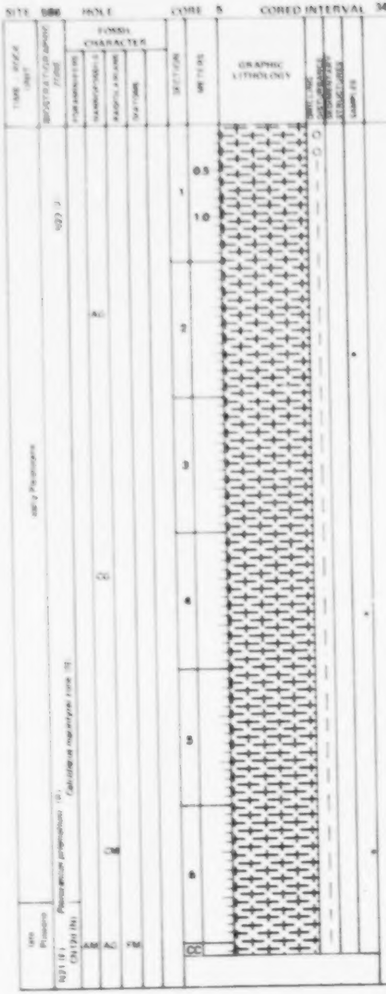
SMEAR SLIDE SUMMARY (%):

	1, 83	2, 56	4, 118	6, 32
	M	D	M	D
Texture:				
Sand	1	15	2	3
Silt	15	35	13	25
Clay	84	50	85	72
Composition:				
Zeolite	–	<1	–	–
Foraminifers	16	50	15	28
Calc. nannofossils	84	50	85	72
Diatoms	<1	–	–	–
Radiolarians	–	–	<1	<1
Sponge spicules	<1	<1	<1	–
Silicoflagellates	<1	–	–	–
Pteropod	<1	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	4, 92–94
Organic carbon	–
Carbonate	89

SITE 586 HOLE CORE 5 CORED INTERVAL 34.9–44.4 m sub-bottom, 2262.9–2262.4 m below rig floor


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
N22 (F)
late Pliocene
N21 (F)
CN12d (N)
Pseudoemiliania lacunosa (N)
Calcidiscus macintyrei zone (N)
AG
CG
CM
AM
AG
FM
0.5
1.0
1
2
3
4
5
6
CC

LITHOLOGIC DESCRIPTION

FORAM-BEARING NANNOFOSSIL OOZE

Dominant color appears as very pale green (about white (5Y 8/1) to pale greenish yellow (10Y 8/2)) with mottles of pale yellow (5Y 7/3); thin layers (most < 1 cm) of darker green (pale green (5G 7/2) to grayish green (5G 5/2)) occur throughout — most are very faint and appear as more or less distinct color tinges in pale green background ooze. Dark gray (N3) blebs and small mottles (<1 cm) also occur throughout and probably represent burrow fills.

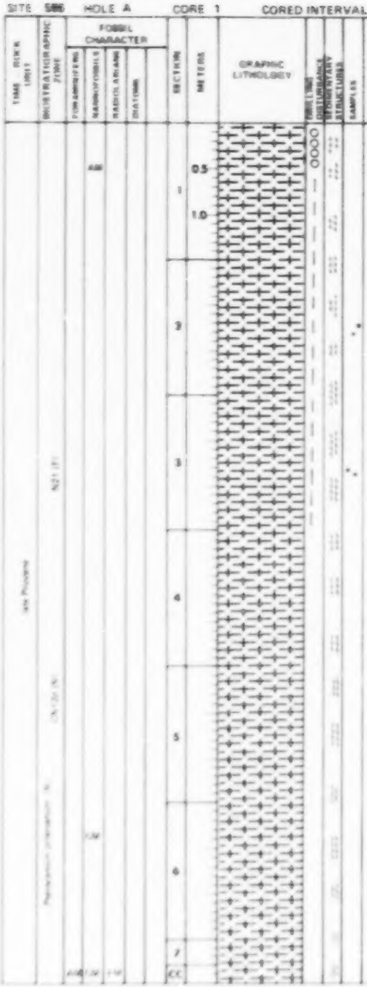
SMEAR SLIDE SUMMARY (%)

	4, 90	6, 93
	D	M
Texture:		
Sand	2	1
Silt	18	18
Clay	80	81
Composition:		
Pyrite	—	2
Zeolite	<1	<1
Foraminifers	20	17
Calc. nannofossils	80	81
Radiolarians	<1	<1
Sponge spicules	—	<1
Pteropods	<1	—

ORGANIC CARBON AND CARBONATE (%)

	2, 105–106
Organic carbon	0.29
Carbonate	88

SITE 586 HOLE A CORE 1 CORED INTERVAL 44.4–54.0 m sub-bottom; 2262.4–2272.0 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
N21 (F)
CN12d (N)
Pterocanium prismatium (R)
AM
CM
AM AG FM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) and pale greenish gray (10Y 8/2) with very indistinct layers of light greenish gray (5GY 8/1); gray burrow mottles (slightly pyritiferous) N7–N3 throughout.

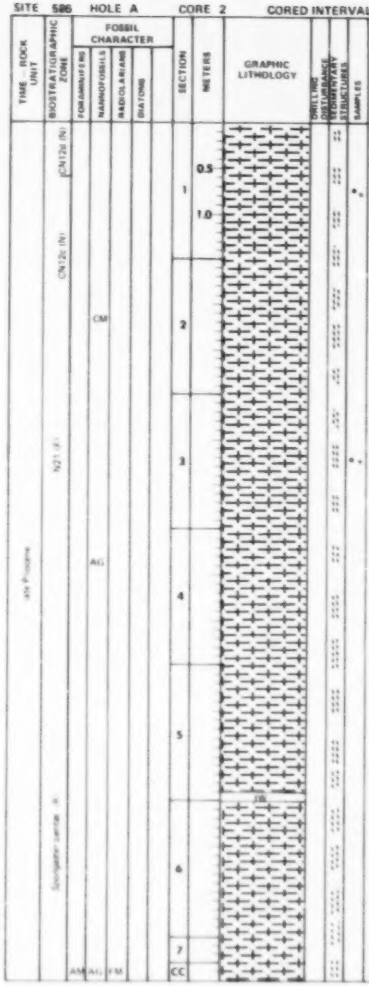
SMEAR SLIDE SUMMARY (%)

	2, 80	3, 88	3, 82
	D	M	M
Texture:			
Sand	8	3	12
Silt	12	10	3
Clay	80	87	85
Composition:			
Volcanic glass	—	<1	—
Pyrite	—	1	—
Foraminifers	10	10	15
Calc. nannofossils	86	89	82
Diatoms	1	<1	1
Radiolarians	2	<1	1
Sponge spicules	<1	—	1
Silicoflagellates	<1	—	1

ORGANIC CARBON AND CARBONATE (%)

	2, 79–80
Organic carbon	0.29
Carbonate	88

SITE 586 HOLE A CORE 2 CORED INTERVAL 54.0–63.6 m sub-bottom; 2272.0–2281.6 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
CN12d (N)
CN12c (N)
N21 (F)
Spongaster pentas (R)
CM
AG
AM AG FM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is "pale green" – approximately white (5Y 8/1) to light greenish gray (5GY 8/1).

Mottles of pale yellow (5Y 7/3) occur throughout.

Dark gray (N3) burrow mottles scattered throughout.

Thin (<1 cm) beds of pale green (5G 7/2) occur throughout. Only a few are very distinct, most are very faint and appear mainly as slightly greener tinges in pale green dominant color.

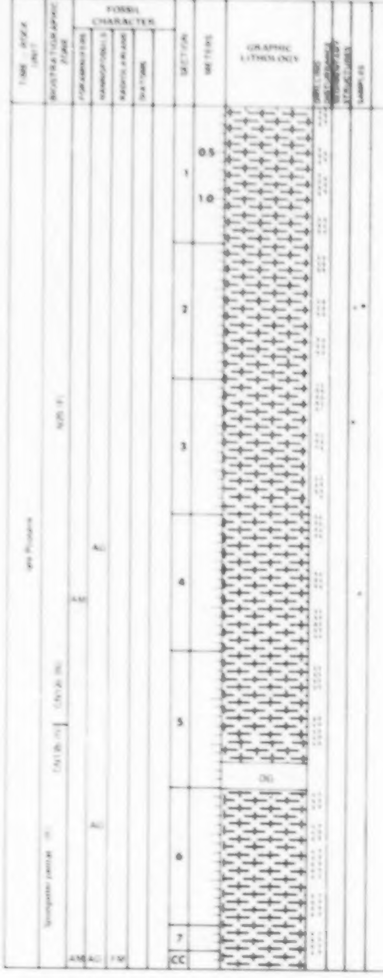
SMEAR SLIDE SUMMARY (%)

	1, 75	2, 90	3, 70
	M	M	D
Texture:			
Sand	18	13	5
Silt	2	9	3
Clay	80	78	92
Composition:			
Volcanic glass	<1	<1	–
Carbonate unspec.	1	1	1
Foraminifers	20	16	10
Calc. nannofossils	78	83	85
Diatoms	<1	<1	1
Radiolarians	<1	1	1
Sponge spicules	–	<1	2
Silicoflagellates	<1	<1	<1

ORGANIC CARBON AND CARBONATE (%)

	1, 75–76	3, 70–71
Organic carbon	–	0.24
Carbonate	88	88

SITE 586 HOLE A CORE 3 CORED INTERVAL 63.6–73.2 m sub-bottom, 2281.6–2291.2 m below rig floor


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
N21 (F)
CN12c (N)
CN12b (N)
AG
AM
AG
AM AG FM
0.5
1.0
1
2
3
4
5
6
7
CC
(N)

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1). Mottles of pale yellow (5Y 7/3) throughout. Burrow mottles dark gray (N3) throughout.

Very, very faint beds (<1 cm) of pale green (5G 7/2) occur throughout, most appear as only slightly greener tinges in dominant 'pale green' ooze.

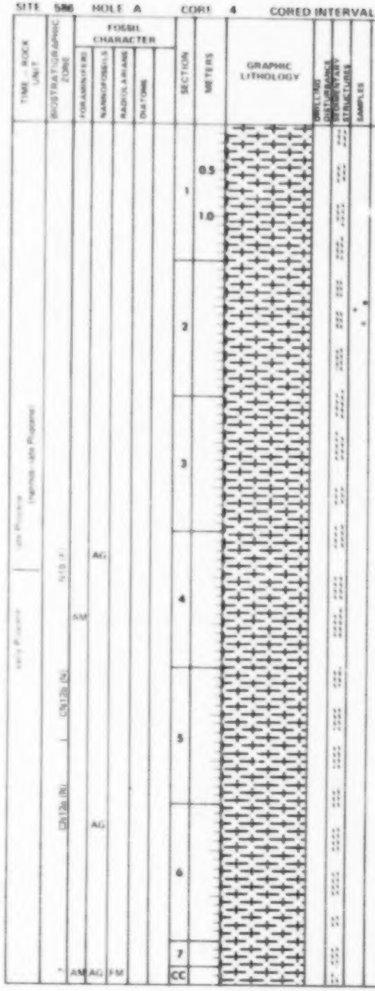
SMEAR SLIDE SUMMARY (%):

	2, 70	3, 46	4, 87
	D	M	M
Texture:			
Sand	12	8	12
Silt	5	5	5
Clay	83	87	83
Composition:			
Heavy minerals	–	<1	–
Volcanic glass	–	–	<1
Pyrite	–	<1	–
Carbonate unspec.	3	5	<1
Foraminifers	12	11	12
Calc. nannofossils	81	83	88
Diatoms	<1	–	–
Radiolarians	3	1	1
Sponge spicules	1	<1	<1
Plant debris	–	<1	–

ORGANIC CARBON AND CARBONATE (%):

	2, 68–70
Organic carbon	–
Carbonate	88

SITE 586 HOLE A CORE 4 CORED INTERVAL 73.2–82.8 m sub-bottom, 2291.2–2300.8 m below rig floor


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
(reworked late Pliocene)
early Pliocene
N19 (F)
CN12b (N)
CN12a (N)
AG
AM
AG
AM AG FM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFERA-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1). Mottles of pale yellow (5Y 7/3) occur throughout. Burrow mottles of dark gray (N3) common throughout.

Thin beds (mostly <1 cm) of pale green (5G 7/2) material throughout, most appear as slightly greener material in light green ooze that is dominant lithology.

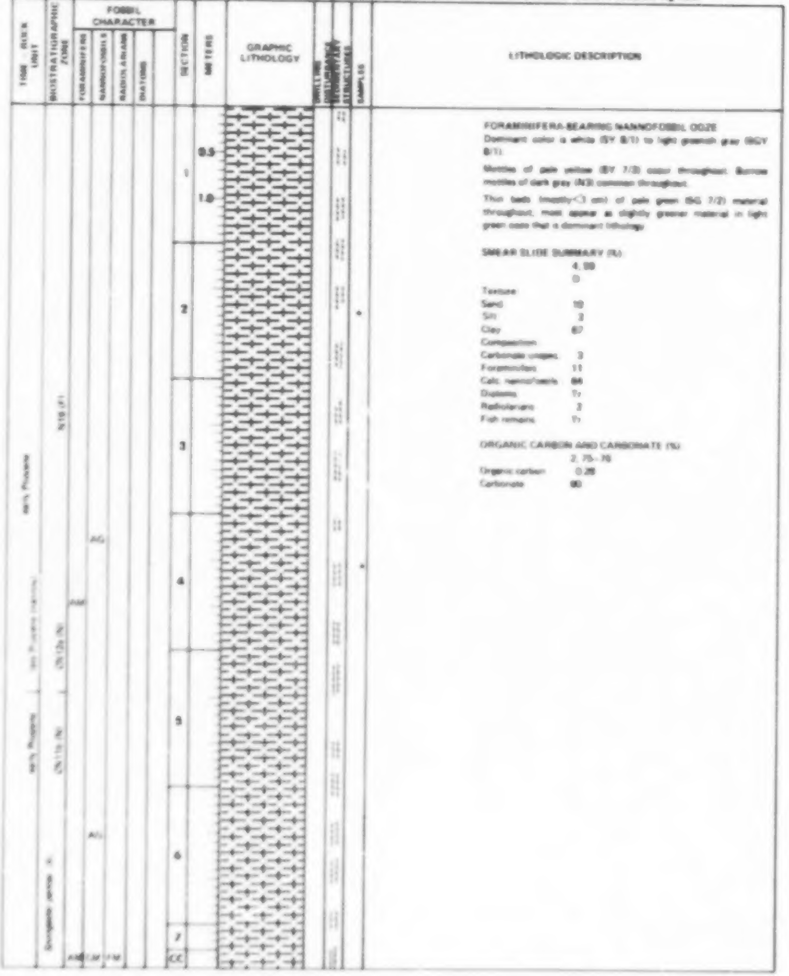
SMEAR SLIDE SUMMARY (%):

	2, 61	2, 70
	D	M
Texture:		
Sand	12	9
Silt	4	3
Clay	84	88
Composition:		
Volcanic glass	–	<1
Pyrite	–	<1
Carbonate unspec.	1	3
Foraminifers	11	10
Calc. nannofossils	87	86
Diatoms	–	<1
Radiolarians	1	<1
Fish remains	–	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 48–49
Organic carbon	–
Carbonate	89

SITE 586 HOLE A CORE 5 CORED INTERVAL 82.8–92.4 m sub-bottom; 2300.8–2310.4 m below rig floor


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
N19 (F)
CN12a (N)
CN11b (N)
Spongaster pentas (R)
AG
AM
AG
AM CM FM
0.5
1.0
1
2
3
4
5
6
7
CC

FORAMINIFERA-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1).

Mottles of pale yellow (5Y 7/3) color throughout. Burrow mottles of dark gray (N3) common throughout.

Thin beds (mostly <1 cm) of pale green (5G 7/2) material throughout, most appear as slightly greener material in light green ooze that is dominant lithology.

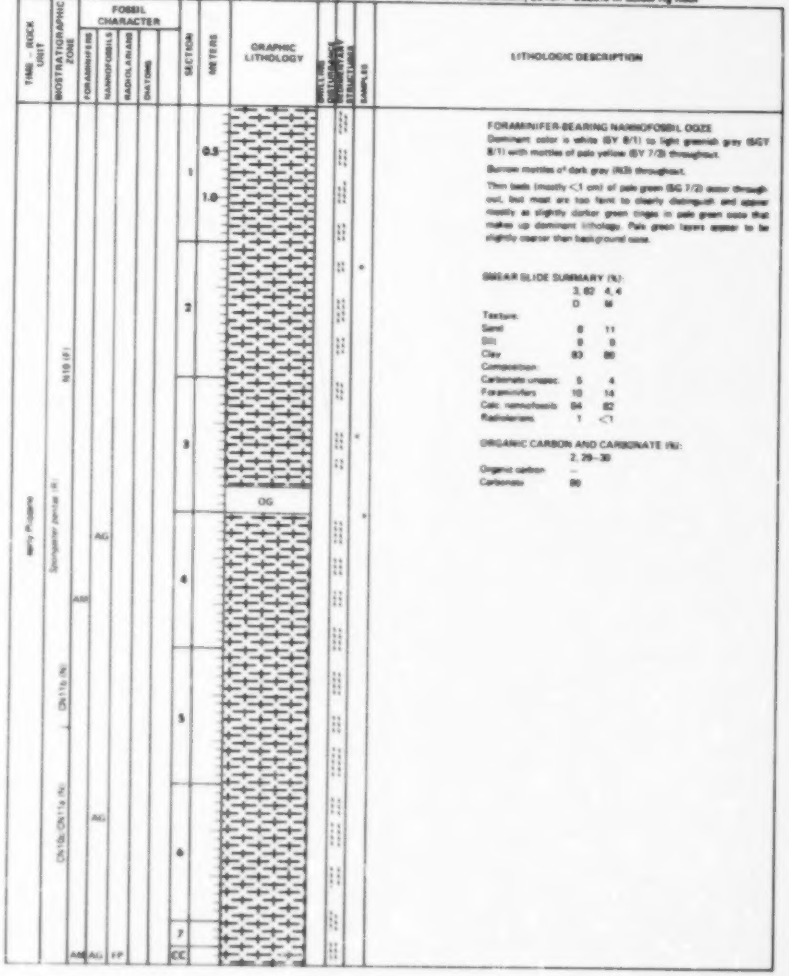
SMEAR SLIDE SUMMARY (%):

	4, 99
	D
Texture:	
Sand	10
Silt	3
Clay	87
Composition:	
Carbonate unspec.	3
Foraminifers	11
Calc. nannofossils	84
Diatoms	Tr
Radiolarians	2
Fish remains	Tr

ORGANIC CARBON AND CARBONATE (%):

	2, 75–76
Organic carbon	0.28
Carbonate	90

SITE 586 HOLE A CORE 6 CORED INTERVAL 92.4–102.0 m sub-bottom; 2310.4–2320.0 m below rig floor


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
N19 (F)
Spongaster pentas (R)
CN11b (N)
CN10c/CN11a (N)
AG
AM
AG
AM AG FP
OG
0.5
1.0
1
2
3
4
5
6
7
CC

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1) with mottles of pale yellow (5Y 7/3) throughout.

Burrow mottles of dark gray (N3) throughout.

Thin beds (mostly <1 cm) of pale green (5G 7/2) occur throughout, but most are too faint to clearly distinguish and appear mostly as slightly darker green tinges in pale green ooze that makes up dominant lithology. Pale green layers appear to be slightly coarser than background ooze.

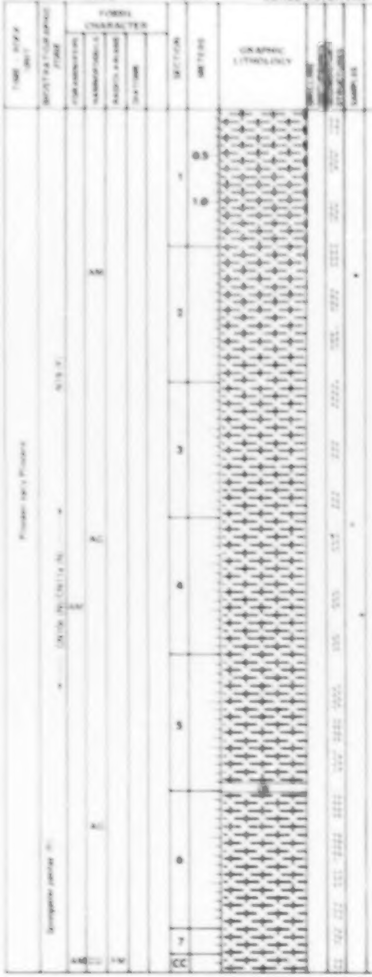
SMEAR SLIDE SUMMARY (%):

	3, 62	4, 4
	D	M
Texture:		
Sand	8	11
Silt	9	9
Clay	83	80
Composition:		
Carbonate unspec.	5	4
Foraminifers	10	14
Calc. nannofossils	84	82
Radiolarians	1	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 29–30
Organic carbon	—
Carbonate	90

SITE 586 HOLE A CORE 7 CORED INTERVAL 102.0–111.6 m sub-bottom; 2320.0–2329.6 m below rig floor


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Pliocene early Pliocene
N19 (F)
CN10c/CN11a (N)
Spongaster pentas (R)
AM
AG
AG
AM
AM CG FM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1) with abundant mottles of pale yellow (5Y 7/3) and burrow mottles of dark gray (N3) throughout.

Thin beds of pale green (5G 7/2) are present throughout but most are too faint to distinguish.

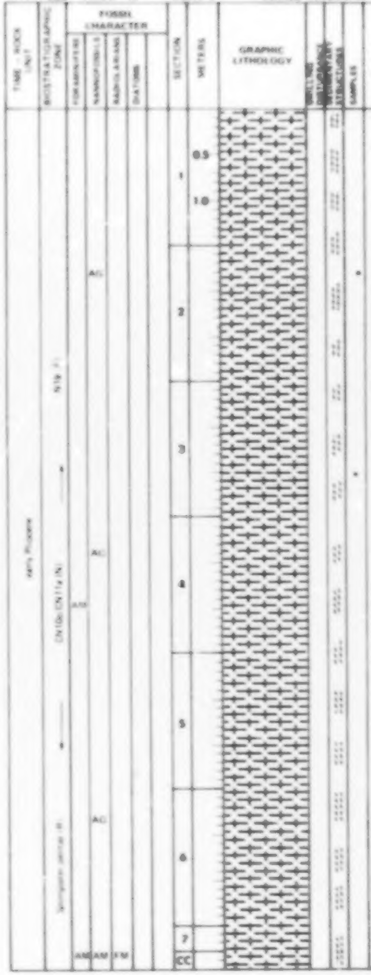
SMEAR SLIDE SUMMARY (%)

	4, 10	4, 106
	M	D
Texture		
Sand	14	8
Silt	5	7
Clay	81	85
Composition		
Carbonate unspec.	4	2
Foraminifers	16	10
Calc. nannofossils	79	88
Radiolarians	2	2
Sponge spicules	<1	—

ORGANIC CARBON AND CARBONATE (%)

	2, 35–36
Organic carbon	—
Carbonate	94

SITE 586 HOLE A CORE 8 CORED INTERVAL 111.6–121.2 m sub-bottom; 2329.6–2339.2 m below rig floor


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
N19 (F)
CN10c/CN11a (N)
Spongaster pentas (R)
AG
AM
AG
AG
AM AM FM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1), with abundant mottles of pale yellow (5Y 7/3) and burrow mottles of dark gray (N3) throughout. Thin beds of slightly darker pale green (5G 7/2) occur throughout dominant ooze but most are too faint to distinguish clearly.

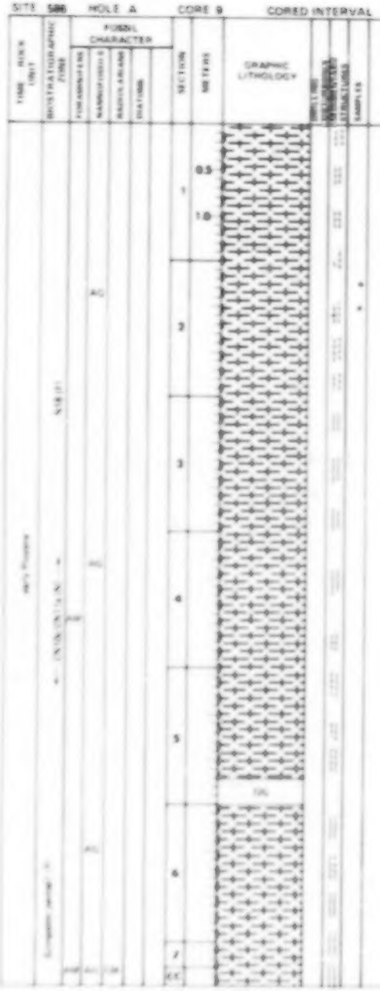
SMEAR SLIDE SUMMARY (%)

	3, 102
	D
Texture	
Sand	17
Silt	3
Clay	80
Composition	
Carbonate unspec.	2
Foraminifers	20
Calc. nannofossils	77
Radiolarians	1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%)

	2, 31–32
Organic carbon	0.82
Carbonate	85

SITE 586 HOLE A CORE 9 CORED INTERVAL 121.2–130.8 m sub-bottom; 2339.2–2348.8 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
N18 (F)
0.5
1.0
1
2
3
4
5
6
7
CC
AG
AM
CM

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1) with mottles of dark gray (N3) material as burrow fill and larger mottles of pale green (5G 7/2) and pale yellow (5Y 7/3).

Thin beds (max<1 cm) of paler green (5G 7/2) material occur throughout although most are too faint to distinguish clearly.

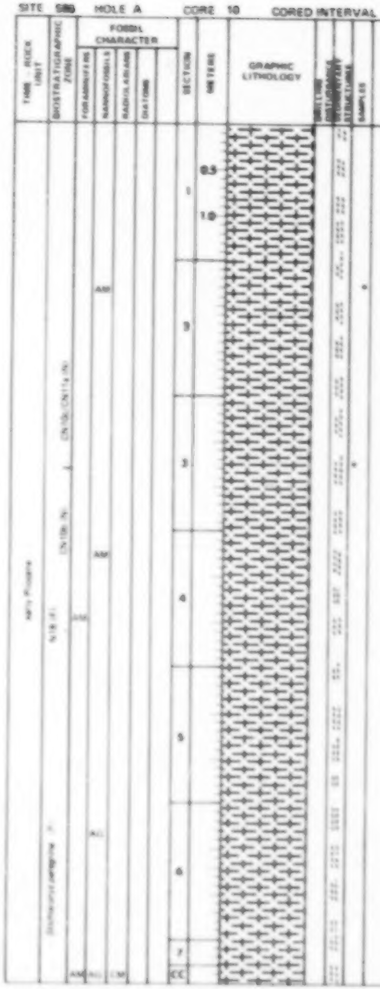
SMEAR SLIDE SUMMARY (%):

	2, 56
	D
Texture:	
Sand	5
Silt	15
Clay	80
Composition:	
Carbonate unspec.	2
Foraminifers	23
Calc. nannofossils	75
Radiolarians	<1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 27–28
Organic carbon	0.07
Carbonate	89

SITE 586 HOLE A CORE 10 CORED INTERVAL 130.8–140.4 m sub-bottom; 2348.8–2358.4 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
N18 (F)
CN10b (N)
0.5
1.0
1
2
3
4
5
6
7
CC
AM
AG
CM

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9 and 5Y 8/1) to light greenish gray (5GY 8/1) with mottles of pale yellow (5Y 7/3) and burrow mottles of dark gray (N3) common throughout. Thin layers of pale green (5G 7/2) material (slightly coarser) occur throughout but most are too faint to be clearly distinguished and appear mainly as faint, slightly darker green tinges and mottles in dominant white to pale green ooze.

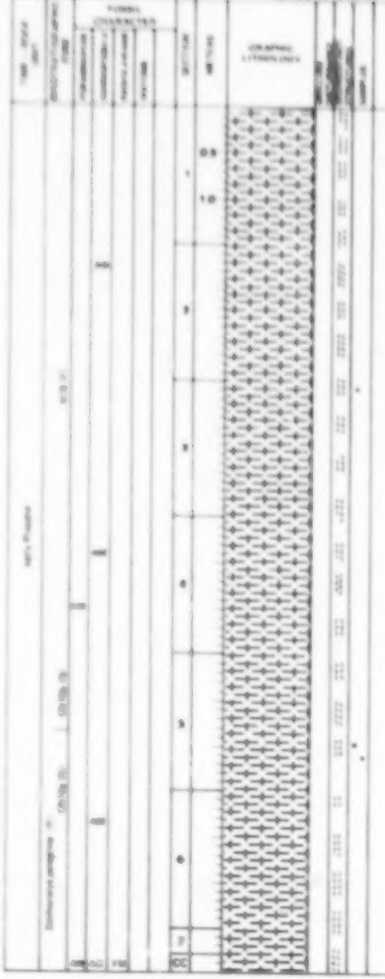
SMEAR SLIDE SUMMARY (%):

	3, 74
Texture:	
Sand	14
Silt	4
Clay	82
Composition:	
Pyrite	<1
Carbonate unspec.	3
Foraminifers	18
Calc. nannofossils	77
Diatoms	<1
Radiolarians	2
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	3, 30–31
Organic carbon	–
Carbonate	86

SITE 586 HOLE A CORE 11 CORED INTERVAL [illegible] m sub-bottom, [illegible] m below rig floor



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Section 1 to Section 5, 35 cm: dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1). Material is extremely bioturbated with burrow mottles of medium gray (N5) and slightly darker shades of pale green (about 5G 7/2) than dominant "pale green" ooze. There are no clearly distinguishable beds of green material.

Section 5, 35 cm to bottom: homogeneous white (N9 to 5Y 8/1) ooze.

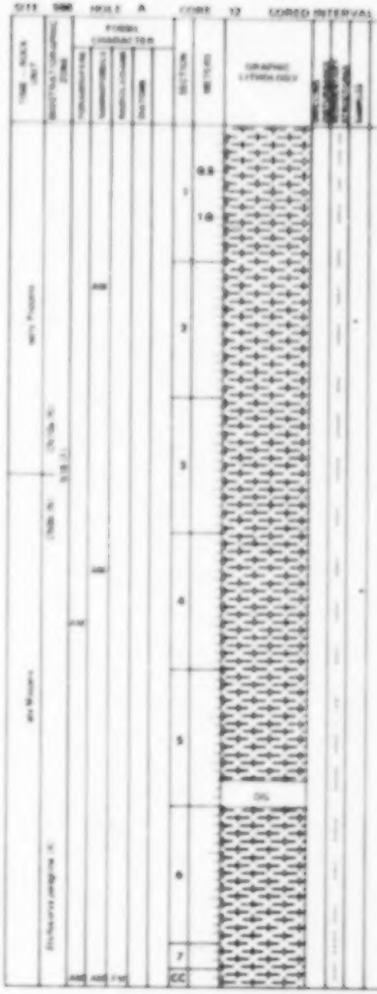
SMEAR SLIDE SUMMARY (%):

	3, 10	5, 112
	M	D
Texture:		
Sand	15	12
Silt	4	7
Clay	81	81
Composition:		
Pyrite	<1	<1
Carbonate unspec.	2	2
Foraminifers	18	17
Calc. nannofossils	77	79
Diatoms	<1	
Radiolarians	2	2
Sponge spicules	<1	<1

ORGANIC CARBON AND CARBONATE (%):

	5, 100-101
Organic carbon	–
Carbonate	87

SITE 586 HOLE A CORE 12 CORED INTERVAL [illegible] m sub-bottom, [illegible] m below rig floor



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1). Entirely bioturbated with burrow mottles of medium gray (N5) and slightly darker pale green (5G 7/2) than the dominant pale green ooze. There are no clearly distinguishable beds.

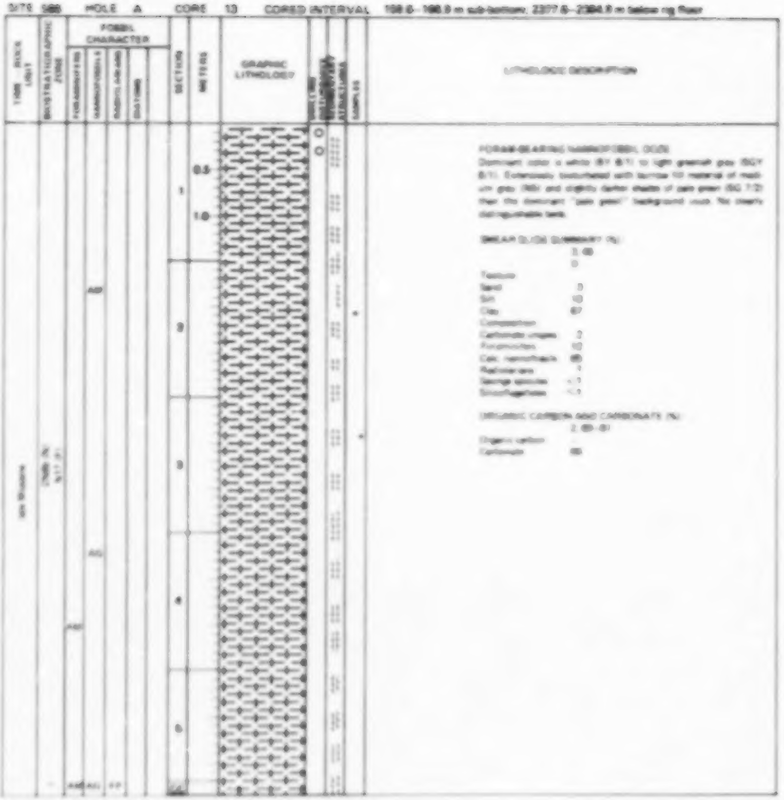
SMEAR SLIDE SUMMARY (%):

	4, 85
	D
Texture:	
Sand	2
Silt	8
Clay	90
Composition:	
Volcanic glass	<1
Foraminifers	10
Calc. nannofossils	90
Radiolarians	<1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 64-65
Organic carbon	0
Carbonate	86

SITE 586 HOLE A CORE 13 CORED INTERVAL 159.6–166.9 m sub-bottom; 2377.6–2384.9 m below rig floor


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
CN9b (N)
N17 (F)
A/M
A/G
A/M
0.5
1.0
1
2
3
4
5

FORAM-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) to light greenish gray (5GY 8/1). Extensively bioturbated with burrow fill material of medium gray (N5) and slightly darker shades of pale green (5G 7/2) than the dominant "pale green" background color. No clearly distinguishable beds.

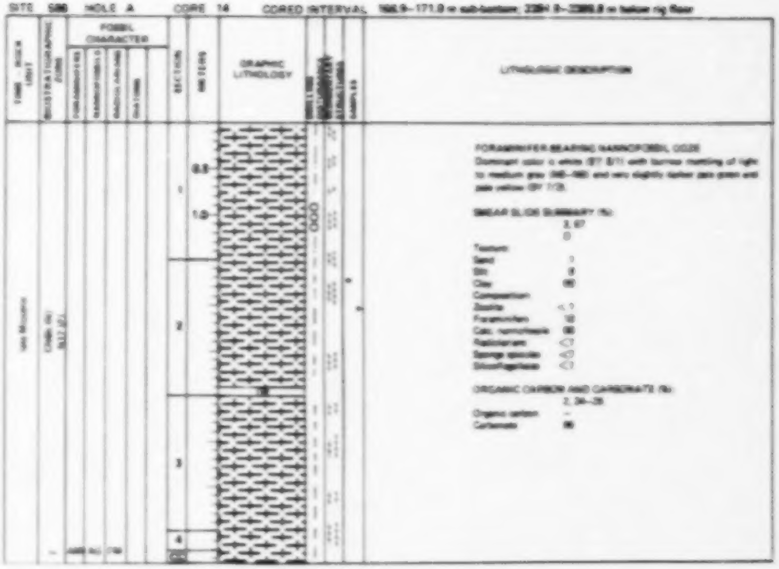
SMEAR SLIDE SUMMARY (%):

	3, 60
	D
Texture:	
Sand	3
Silt	10
Clay	87
Composition:	
Carbonate unspec.	2
Foraminifers	10
Calc. nannofossils	85
Radiolarians	1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 60–61
Organic carbon	–
Carbonate	86

SITE 586 HOLE A CORE 14 CORED INTERVAL 166.9–171.0 m sub-bottom; 2384.9–2389.0 m below rig floor


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
CN9b (N)
N17 (F)
A/M
0.5
1.0
1
2
3
4

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (5Y 8/1) with burrow mottling of light to medium gray (N6–N5) and very slightly darker pale green and pale yellow (5Y 7/3).

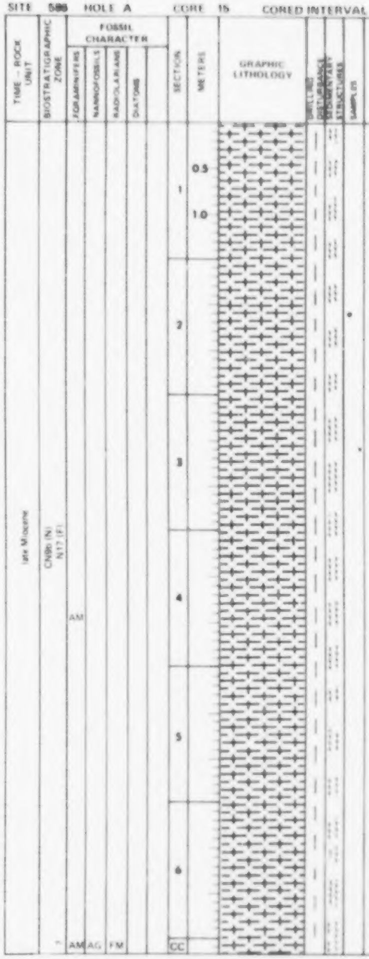
SMEAR SLIDE SUMMARY (%):

	2, 67
	D
Texture:	
Sand	1
Silt	9
Clay	90
Composition:	
Zeolite	<1
Foraminifers	10
Calc. nannofossils	88
Radiolarians	<1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 24–25
Organic carbon	–
Carbonate	89

SITE 586 HOLE A CORE 15 CORED INTERVAL 171.8–180.8 m sub-bottom; 2389.8–2398.8 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9b (N)
N17 (F)
AM
AM
AG
FM
0.5
1.0
1
2
3
4
5
6
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (5Y 8/1) with light to medium gray (N7–N5), pale yellow, and pale green burrow mottles throughout. Outlines of burrow mottles are indistinct.

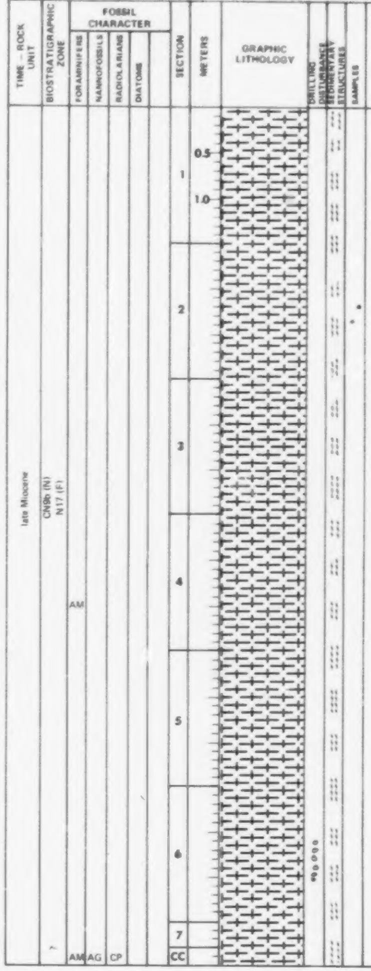
SMEAR SLIDE SUMMARY (%):

	3, 60
	D
Texture:	
Sand	2
Silt	10
Clay	88
Composition:	
Zeolite	<1
Foraminifers	12
Calc. nannofossils	88
Radiolarians	<1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 60–61
Organic carbon	0.02
Carbonate	98

SITE 586 HOLE A CORE 16 CORED INTERVAL 180.8–190.4 m sub-bottom; 2398.8–2408.4 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9b (N)
N17 (F)
AM
AM
AG
CP
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9 and 5Y 8/1) and light greenish gray (5GY 8/1). Intensely bioturbated throughout with burrow mottles of pale yellow (5Y 7/3), medium gray (N5) and pale green (5G 7/2) material.

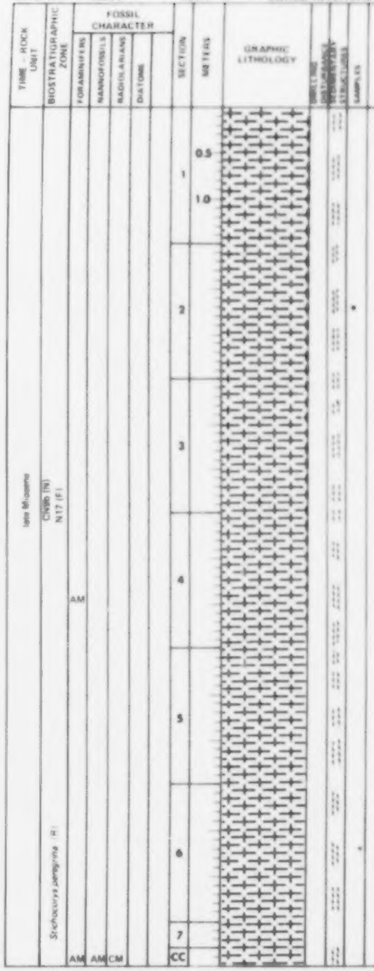
SMEAR SLIDE SUMMARY (%):

	2, 86
	D
Texture:	
Sand	2
Silt	10
Clay	88
Composition:	
Volcanic glass	<1
Carbonate unspec.	2
Foraminifers	12
Calc. nannofossils	86
Radiolarians	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 70–71
Organic carbon	–
Carbonate	96

SITE 586 HOLE A CORE 17 CORED INTERVAL 190.4–200.0 m sub-bottom; 2408.4–2418.0 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9b (N)
N17 (F)
Stichocorys peregrina (R)
AM
AM AM CM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (N9) to bluish white (5B 9/1) with burrow mottlings of pale yellow (5Y 7/3), medium gray (N8), and pale green (5G 7/2) abundant throughout.

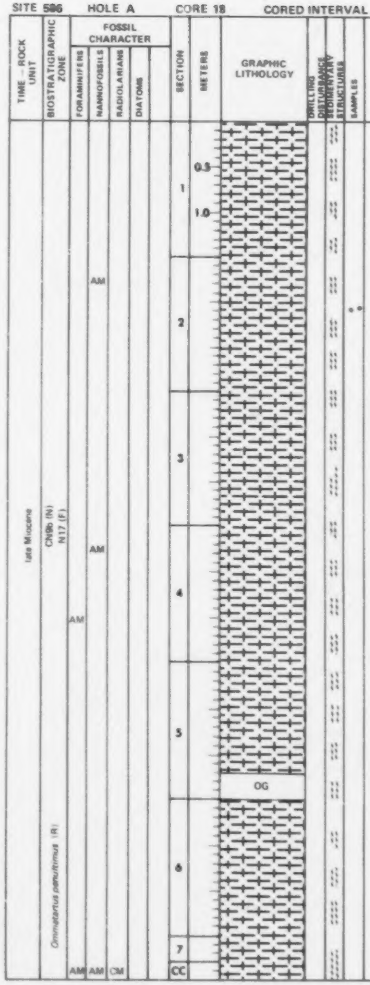
SMEAR SLIDE SUMMARY (%):

	6, 70
	D
Texture:	
Sand	2
Silt	10
Clay	88
Composition:	
Volcanic glass	<1
Carbonate unspec.	3
Foraminifers	10
Calc. nannofossils	87
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 70–71
Organic carbon	–
Carbonate	99

SITE 586 HOLE A CORE 18 CORED INTERVAL 200.0–209.6 m sub-bottom; 2418.0–2427.6 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9b (N)
N17 (F)
Ommatartus penultimus (R)
AM
AM
AM
AM AM CM
0.5
1.0
OG
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (N9) to bluish white (5B 9/1) with abundant burrow mottlings of pale yellow (5Y 7/3), medium gray (N5), and pale green (5G 7/2) material throughout.

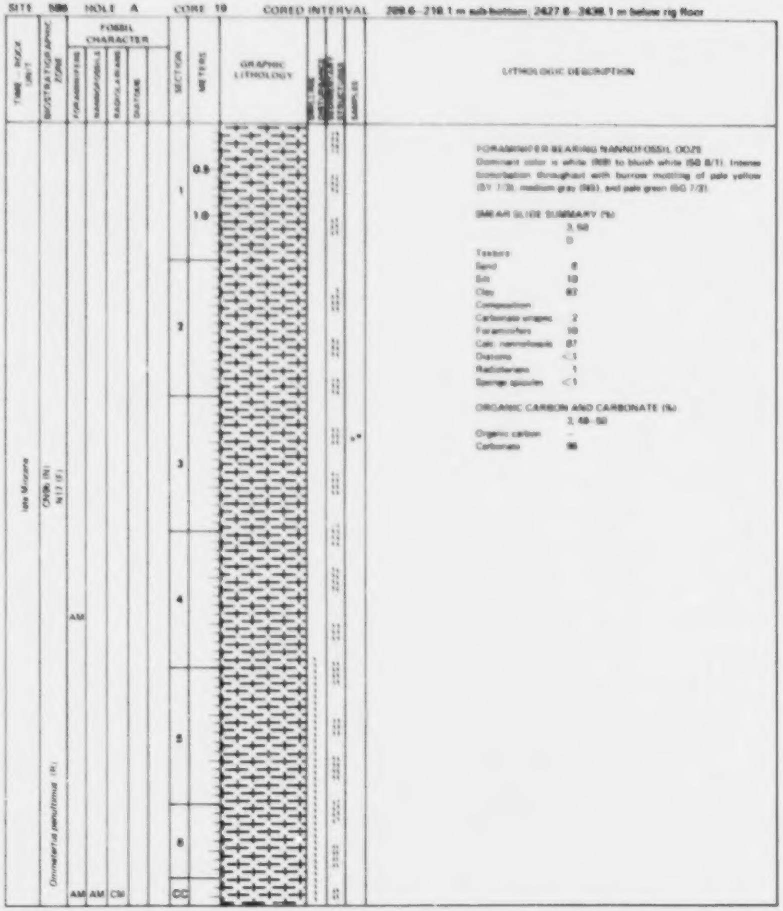
SMEAR SLIDE SUMMARY (%):

	2, 60
	D
Texture:	
Sand	8
Silt	12
Clay	80
Composition:	
Carbonate unspec.	5
Foraminifers	15
Calc. nannofossils	79
Diatoms	<1
Radiolarians	1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 60–61
Organic carbon	0.01
Carbonate	89

SITE 586 HOLE A CORE 19 CORED INTERVAL 209.6–218.1 m sub-bottom; 2427.6–2436.1 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
CN9b (N)
N17 (F)
Ommatartus penultimus (R)
AM
AM AM CM
1
2
3
4
5
6
CC
0.5
1.0

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (N9) to bluish white (5B 8/1). Intense bioturbation throughout with burrow mottling of pale yellow (5Y 7/3), medium gray (N6), and pale green (5G 7/2).

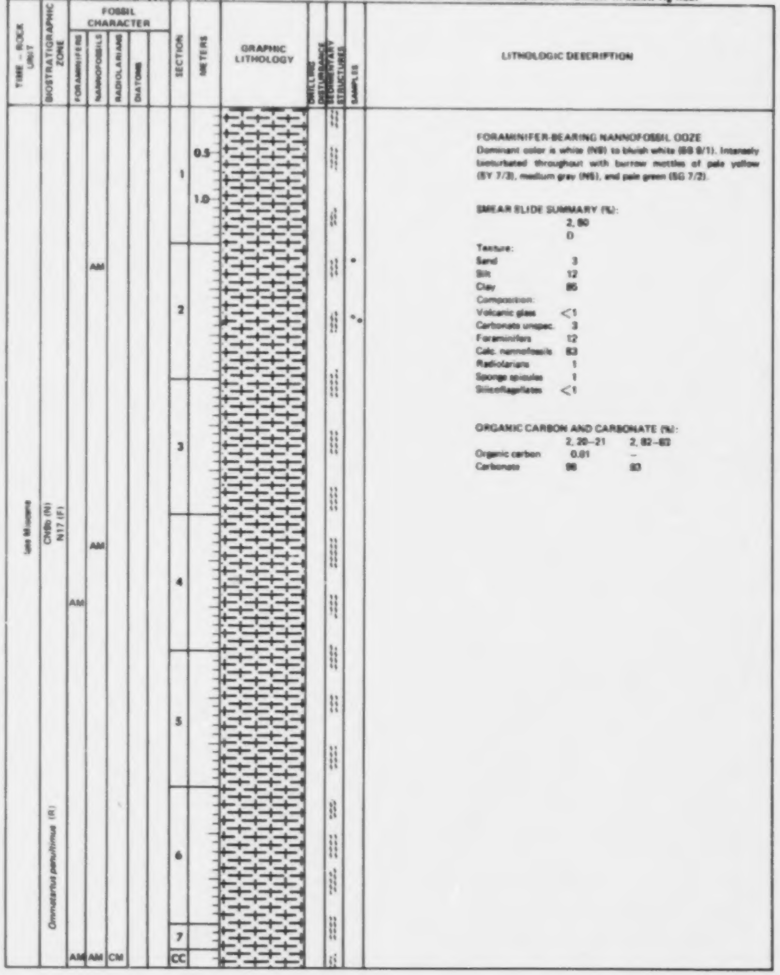
SMEAR SLIDE SUMMARY (%):

	3, 50
	D
Texture:	
Sand	8
Silt	10
Clay	82
Composition:	
Carbonate unspec.	2
Foraminifers	10
Calc. nannofossils	87
Diatoms	<1
Radiolarians	1
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	3, 48–50
Organic carbon	–
Carbonate	96

SITE 586 HOLE A CORE 20 CORED INTERVAL 218.1–227.7 m sub-bottom; 2436.1–2445.7 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
CN9b (N)
N17 (F)
Ommatartus penultimus (R)
AM
AM
AM
AM AM CM
1
2
3
4
5
6
7
CC
0.5
1.0

FORAMINIFER-BEARING NANNOFOSSIL OOZE
Dominant color is white (N9) to bluish white (5B 8/1). Intensely bioturbated throughout with burrow mottles of pale yellow (5Y 7/3), medium gray (N6), and pale green (5G 7/2).

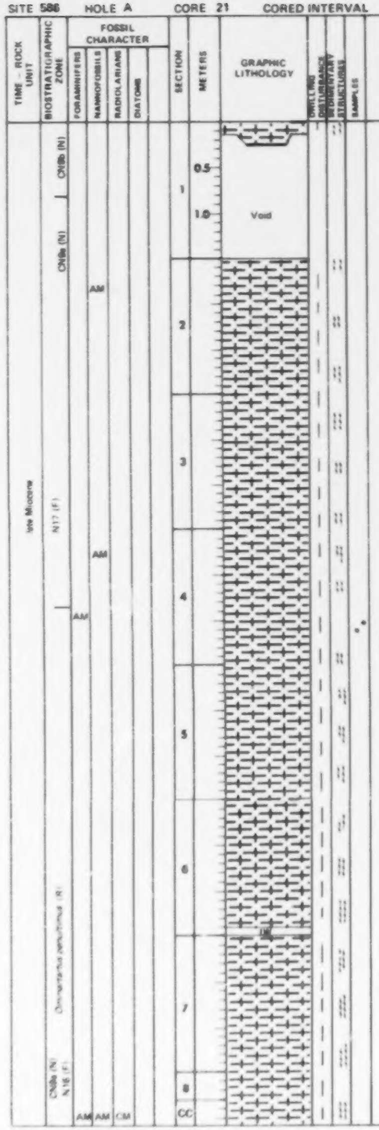
SMEAR SLIDE SUMMARY (%):

	2, 80
	D
Texture:	
Sand	3
Silt	12
Clay	85
Composition:	
Volcanic glass	<1
Carbonate unspec.	3
Foraminifers	12
Calc. nannofossils	83
Radiolarians	1
Sponge spicules	1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	2, 20–21	2, 82–83
Organic carbon	0.01	–
Carbonate	96	83

SITE 586 HOLE A CORE 21 CORED INTERVAL 227.7–237.2 m sub-bottom; 2445.7–2455.3 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9b (N)
CN9a (N)
N17 (F)
Ommatartus penultimus (R)
CN9a (N)
N16 (F)
AM
AM
AM
AM AM CM
0.5
1.0
Void
1
2
3
4
5
6
7
8
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9) to bluish white (5B 9/1). Intense bioturbation throughout, with burrow mottles of pale yellow (5Y 7/3), light to medium gray (N5–N6), and pale green (5G 7/2).

Note: Section 1 is an extra piece found in the barrel after the liner had been removed and sectioned. It was added on as Section 1.

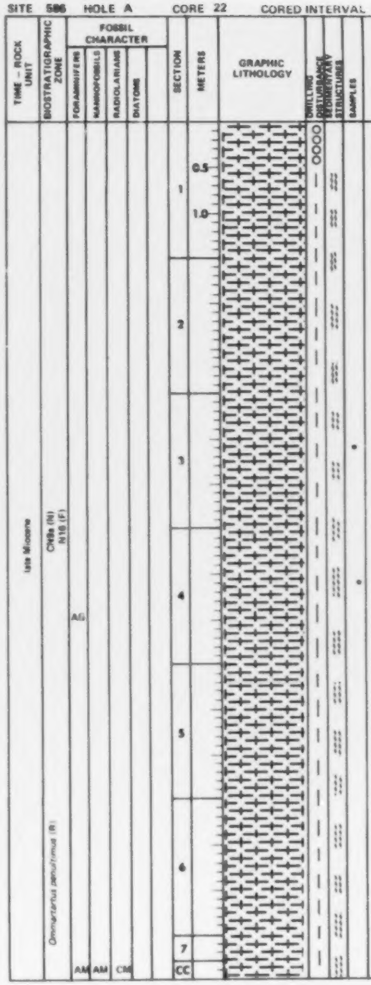
SMEAR SLIDE SUMMARY (%):

	4, 110
	D
Texture:	
Sand	2
Silt	10
Clay	88
Composition:	
Zeolite	<1
Foraminifers	12
Calc. nannofossils	88
Radiolarians	<1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	4, 108–109
Organic carbon	0.03
Carbonate	95

SITE 586 HOLE A CORE 22 CORED INTERVAL 237.3–246.9 m sub-bottom; 2455.3–2464.9 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9a (N)
N16 (F)
Ommatartus penultimus (R)
AG
AM AM CM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

0–60 cm: soupy; flow-in; homogeneous white (N9 to 5B 9/1) ooze.

Rest of core: dominant color is white (N9) to bluish white (5B 9/1). Intensely bioturbated throughout with burrow mottles of pale yellow (5Y 7/3) and some pale green (5G 7/2) and light to medium gray (N7–N5) material.

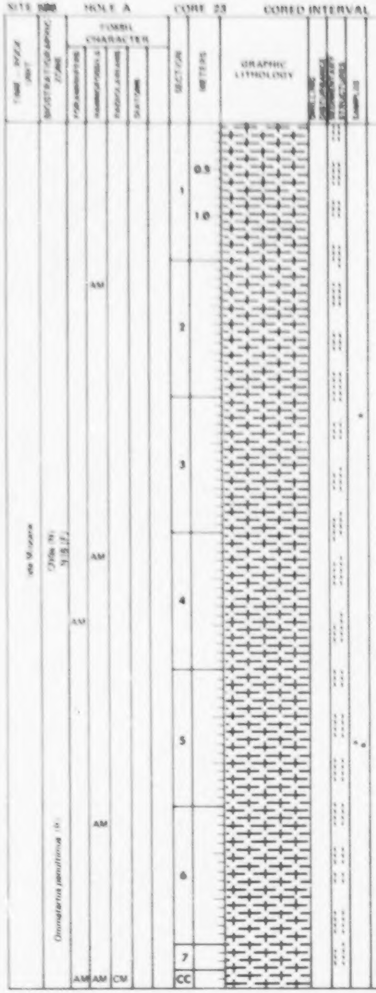
SMEAR SLIDE SUMMARY (%):

	4, 60
	D
Texture:	
Sand	2
Silt	12
Clay	86
Composition:	
Zeolite	<1
Foraminifers	14
Calc. nannofossils	86
Radiolarians	<1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	3, 80–81
Organic carbon	–
Carbonate	92

SITE 586 HOLE A CORE 23 CORED INTERVAL 246.9–256.5 m sub bottom; 2464.9–2474.5 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN9a (N)
N 16 (F)
Ommatartus penultimus (R)
AM
AM
AM
AM
AM AM CM
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE

Dominant color is white (N9) to bluish white (5B 9/1). Intensely bioturbated throughout with burrow mottles of light to medium gray (N7–N3), pale green (5G 7/2) and pale yellow (5Y 7/3), latter being most abundant and forms dominant material in a few parts of core (see SS 3, 20).

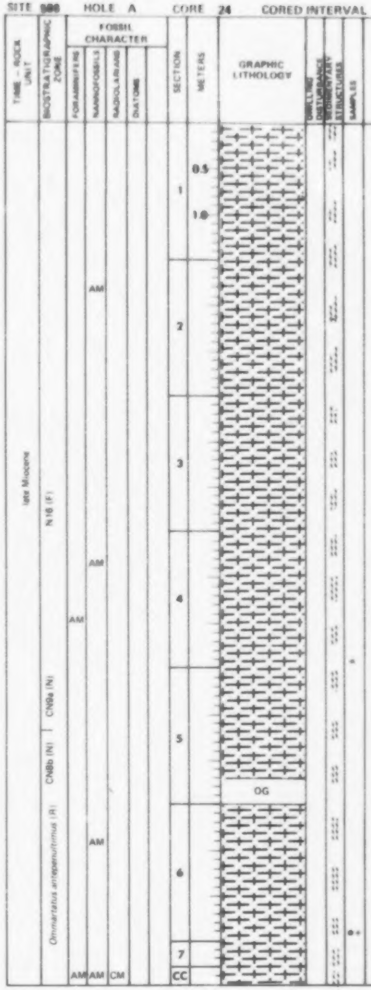
SMEAR SLIDE SUMMARY (%):

	3, 20	5, 80
	M	D
Texture:		
Sand	2	2
Silt	14	14
Clay	84	84
Composition:		
Volcanic glass	<1	–
Pyrite	<1	–
Zeolite	–	<1
Foraminifers	15	16
Calc. nannofossils	84	84
Radiolarians	1	<1
Sponge spicules	<1	<1
Silicoflagellates	<1	–

ORGANIC CARBON AND CARBONATE (%):

	5, 82–83
Organic carbon	0
Carbonate	97

SITE 586 HOLE A CORE 24 CORED INTERVAL 256.5–266.1 m sub-bottom; 2474.5–2484.1 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N 16 (F)
CN9a (N)
CN8b (N)
Ommatartus antepenultimus (R)
AM
AM
AM
AM
AM AM CM
0.5
1.0
1
2
3
4
5
6
7
CC
OG

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9) to bluish white (5B 9/1). Intensely bioturbated throughout with burrow mottles of light to medium gray (N7 to N5), pale green (5GY 8/1), and pale yellow (5Y [illegible]) materials.

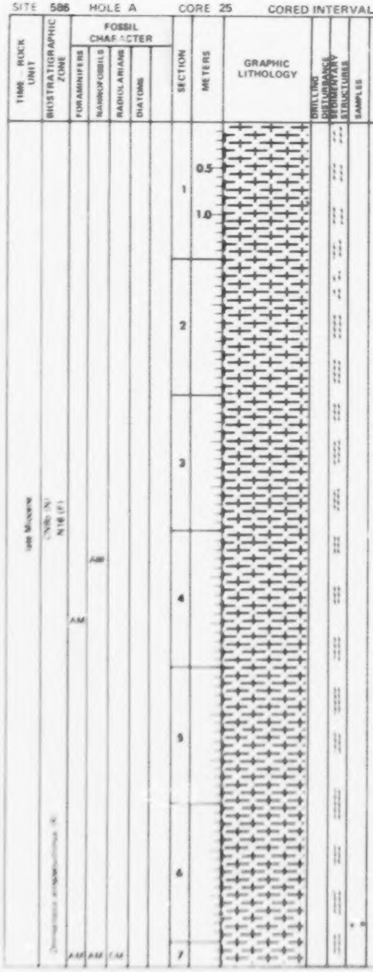
SMEAR SLIDE SUMMARY (%):

	4, 146	6, 146
	M	D
Texture:		
Sand	4	1
Silt	12	12
Clay	84	87
Composition:		
Pyrite	30	–
Zeolite	1	<1
Carbonate unspec.	1	1
Foraminifers	10	13
Calc. nannofossils	58	86
Radiolarians	–	<1

ORGANIC CARBON AND CARBONATE (%):

	6, 145–146
Organic carbon	–
Carbonate	90

SITE 586 HOLE A CORE 25 CORED INTERVAL 266.1–275.7 m sub-bottom; 2484.1–2493.7 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN8b (N)
N16 (F)
Ommartatus antepenultimus (R)
AM
AM
AM AM CM
0.5
1.0
1
2
3
4
5
6
7

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9) to bluish white (5B 9/1), intensely bioturbated throughout, with burrow mottling of light to medium gray (N7–N5), pale yellow (5Y 8/3), and pale green (5GY 8/1) material.

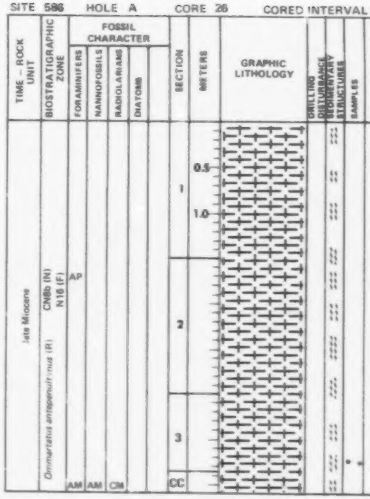
SMEAR SLIDE SUMMARY (%):

	6, 137
	D
Texture:	
Sand	1
Silt	10
Clay	89
Composition:	
Zeolite	<1
Carbonate unspec.	1
Foraminifers	10
Calc. nannofossils	88
Diatoms	<1
Radiolarians	1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	6, 137–138
Organic carbon	–
Carbonate	94

SITE 586 HOLE A CORE 26 CORED INTERVAL 275.7–281.7 m sub-bottom; 2493.7–2499.7 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN8b (N)
N16 (F)
Ommartatus antepenultimus (R)
AP
AM AM CM
0.5
1.0
1
2
3
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE

Dominant color is white (N9) to bluish white (5B 9/1). Bioturbated throughout with burrow mottling of light gray (N7–N5), pale yellow (5Y 8/1), and light greenish gray (5GY 8/1) material.

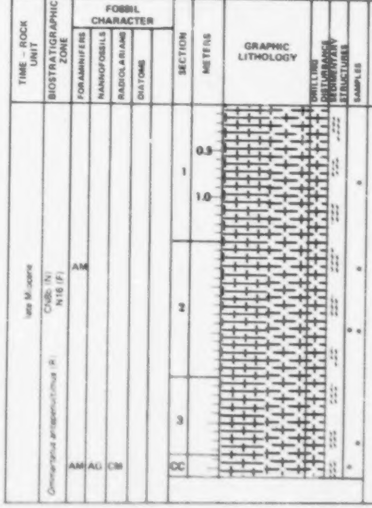
SMEAR SLIDE SUMMARY (%):

	3, 75
	D
Texture:	
Sand	1
Silt	10
Clay	89
Composition:	
Zeolite	<1
Carbonate unspec.	10
Foraminifers	11
Calc. nannofossils	79
Diatoms	<1
Radiolarians	<1
Sponge spicules	<1
Silicoflagellates	<1

ORGANIC CARBON AND CARBONATE (%):

	3, 75–76
Organic carbon	0
Carbonate	93

SITE 586 HOLE A CORE 27 CORED INTERVAL 281.7–286.9 m sub-bottom; 2499.7–2503.4 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN8b (N)
N16 (F)
Ommartatus antepenultimus (R)
AM
AM AG CM
0.5
1.0
1
2
3
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL STIFF OOZE TO CHALK

Sections 1 and 2 are mostly ooze. By Section 3, chalk "nodules" occur about every 15–20 cm with firm ooze between.

Dominant color is white (N9) to bluish white (5B 9/1).

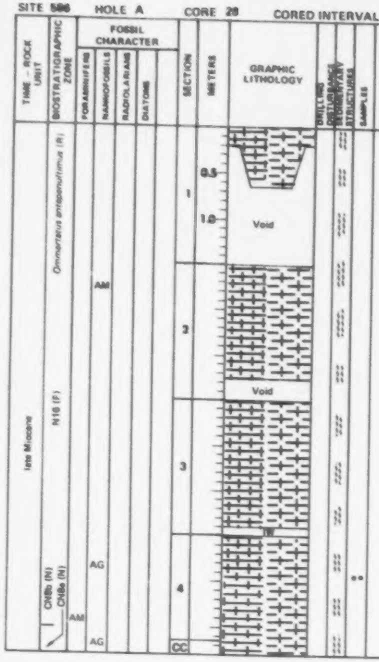
SMEAR SLIDE SUMMARY (%):

	1, 83	2, 34	2, 108	3, 74	CC, 8
	D	M	D	M	D
Texture:					
Sand	8	5	10	13	10
Silt	5	3	2	5	3
Clay	87	92	88	82	87
Composition:					
Clay	–	6	–	–	3
Volcanic glass	–	–	–	<1	<1
Pyrite	<1	–	<1	–	–
Carbonate unspec.	5	7	7	10	9
Foraminifers	12	10	13	15	15
Calc. nannofossils	80	68	74	72	67
Diatoms	<1	1	–	<1	1
Radiolarians	3	4	4	3	5
Sponge spicules	<1	7	2	<1	–
Silicoflagellates	–	1	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	2, 108–108
Organic carbon	–
Carbonate	93

SITE 586 HOLE A CORE 28 CORED INTERVAL 285.9–290.3 m sub-bottom; 2503.9–2508.3 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
Ommatartus antepenultimus (R)
N16 (F)
CN8b (N)
CN8a (N)
AM
AG
AM
AG
1
2
3
4
CC
0.5
1.0
Void
Void

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL FIRM OOZE AND CHALK

Dominant color is white (N9) to bluish white (5B 8/1).

Bioturbated throughout but not as much as above cores. Burrow mottles of light to medium gray (N7–N5), pale yellow (5Y 8/1), and light greenish gray (5GY 8/1) are common, but distinguishable, continuous layers of these colors also are common.

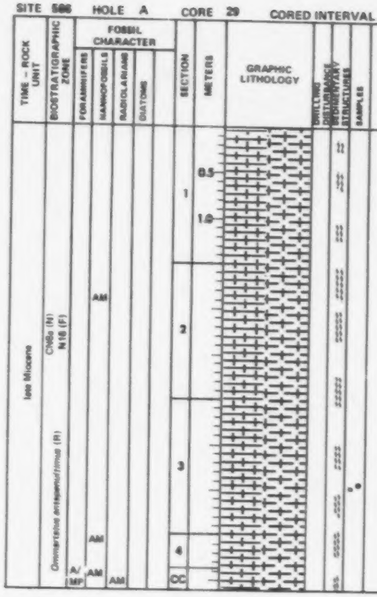
SMEAR SLIDE SUMMARY (%):

	4, 46 D
Texture:	
Sand	10
Silt	3
Clay	87
Composition:	
Carbonate unspec.	3
Foraminifers	10
Calc. nannofossils	85
Diatoms	<1
Radiolarians	2

ORGANIC CARBON AND CARBONATE (%):

	4, 45–48
Organic carbon	0
Carbonate	98

SITE 586 HOLE A CORE 29 CORED INTERVAL 290.3–295.3 m sub-bottom; 2508.3–1513.3 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN8a (N)
N16 (F)
Ommatartus antepenultimus (R)
AM
AM
A/MP
AM
AM
1
2
3
4
CC
0.5
1.0

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL STIFF OOZE AND CHALK

Dominant color is white (N9) to bluish white (5B 8/1).

Bioturbated throughout. Burrow mottles of light to medium gray (N7–N5), pale yellow (10Y 8/2), and greenish gray (5G 6/1) are common. Continuous layers of gray and greenish gray also are common.

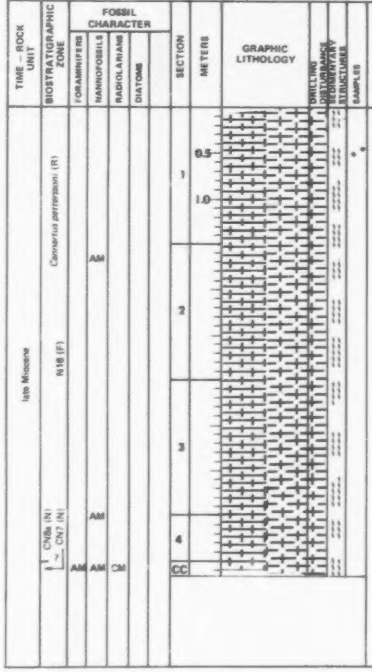
SMEAR SLIDE SUMMARY (%):

	3, 100 D
Texture:	
Sand	15
Silt	4
Clay	81
Composition:	
Carbonate unspec.	4
Foraminifers	12
Calc. nannofossils	78
Diatoms	<1
Radiolarians	6
Fish remains	<1

ORGANIC CARBON AND CARBONATE (%):

	3, 98–100
Organic carbon	–
Carbonate	96

SITE 586 HOLE A CORE 30 CORED INTERVAL 295.3–300.3 m sub-bottom; 2513.3–2518.3 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
Cannartus petterssoni (R)
N18 (F)
CN8a (N)
CN7 (N)
?
AM
AM
AM
AM
CM
0.5
1.0
1
2
3
4
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL STIFF OOZE AND CHALK

Dominant color is white (N9) to bluish white (5B 9/1).

Bioturbated throughout, with burrow mottles of light to medium gray (N7–N5), pale greenish yellow (5Y 8/2), and greenish gray (5G 8/1). Continuous layers of greenish gray and gray also are common.

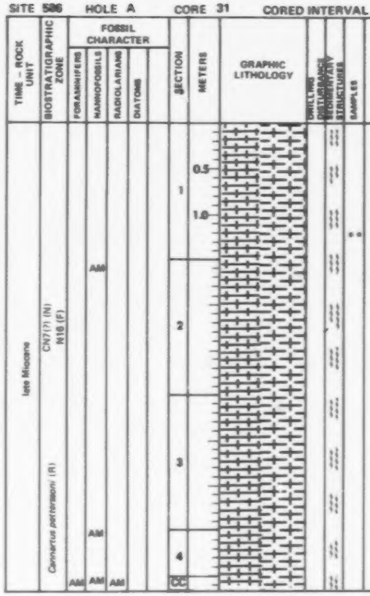
SMEAR SLIDE SUMMARY (%):

	1, 56
	D
Texture:	
Sand	13
Silt	4
Clay	83
Composition:	
Carbonate unspec.	2
Foraminifers	12
Calc. nannofossils	83
Diatoms	<1
Radiolarians	3
Sponge spicules	<1

ORGANIC CARBON AND CARBONATE (%):

	1, 54–55
Organic carbon	0
Carbonate	96

SITE 586 HOLE A CORE 31 CORED INTERVAL 300.3–305.3 m sub-bottom; 2518.3–2523.3 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
CN7(?) (N)
N18 (F)
Cannartus petterssoni (R)
AM
AM
AM
AM
AM
0.5
1.0
1
2
3
4
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL STIFF OOZE AND CHALK

Dominant color is white (N9) to bluish white (5B 9/1). Bioturbated throughout but not as much as above cores. Burrow mottles of light to medium gray (N7–N5), pale greenish yellow (10Y 8/1), and greenish gray (5G 8/1) material are common. Continuous layers of gray, and greenish gray also are common.

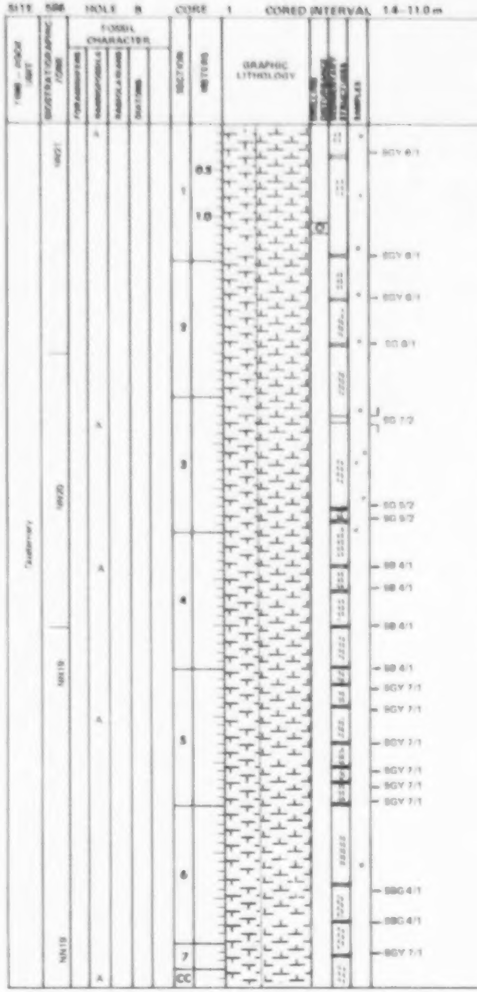
SMEAR SLIDE SUMMARY (%):

	1, 120
	D
Texture:	
Sand	15
Silt	4
Clay	81
Composition:	
Carbonate unspec.	2
Foraminifers	15
Calc. nannofossils	77
Diatoms	<1
Radiolarians	6

ORGANIC CARBON AND CARBONATE (%):

	1, 121–122
Organic carbon	–
Carbonate	98

SITE 586 HOLE B CORE 1 CORED INTERVAL 1.4–11.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21
NN20
NN19
NN19
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5GY 6/1
5GY 6/1
5GY 6/1
5G 6/1
5G 7/2
5G 5/2
5G 5/2
5B 4/1
5B 4/1
5B 4/1
5B 4/1
5GY 7/1
5GY 7/1
5GY 7/1
5GY 7/1
5GY 7/1
5GY 7/1
5BG 4/1
5BG 4/1
5GY 7/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (5Y 7/1), soft, with lamina less than 1 cm thick of various subtle shades of greenish gray (5GY 6/1) to 5G 7/2. The lamina appear to be celadonite(?) representing devitrified volcanic ash. Streaks and blebs of dark bluish gray (5B 4/1) framboids of pyrite and hydrotroilite scattered throughout core. Burrowing common but subtle throughout. Gas pockets(?) appear in Section 4.

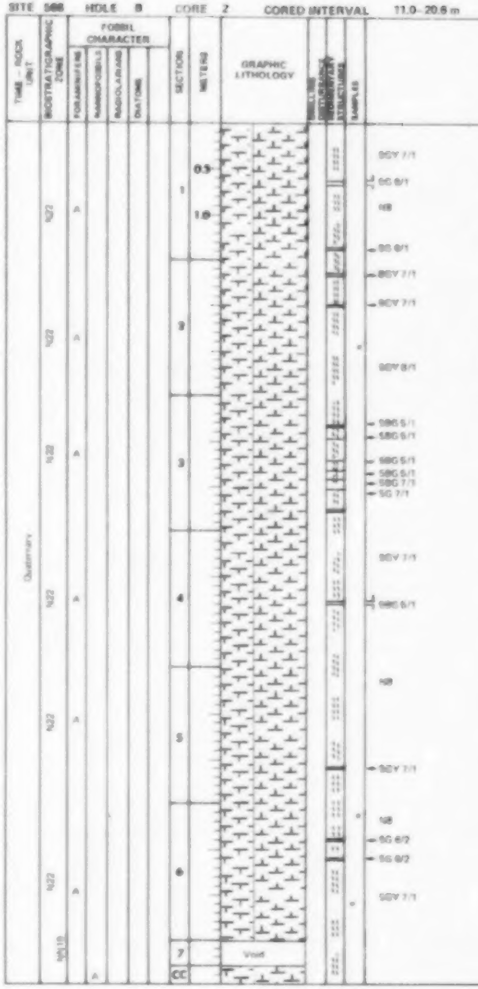
SMEAR SLIDE SUMMARY

	1, 79 D	1, 23 M	1, 141 M	2, 39 M	2, 93 M
Texture:					
Sand	—	R	—	C	C
Silt	C	C	C	A	C
Clay	D	D	D	A	A
Composition:					
Mica	—	—	—	—	T
Heavy minerals	—	T	—	—	—
Clay	—	—	—	—	R
Volcanic glass	—	T	—	T	—
Foraminifers	C	C	C	C	C
Calc. nannofossils	D	D	D	A	A
Diatoms	T	—	—	—	—
Radiolarians	T	R	—	R	R
Sponge spicules	—	—	—	T	—
Other	T	—	—	—	—

SMEAR SLIDE SUMMARY

	3, 27 M	3, 67 M	3, 115 M	4, 2 M	6, 71 M
Texture:					
Sand	R	R	—	—	C
Silt	R	C	R	C	C
Clay	D	D	D	D	A
Composition:					
Pyrite	—	T	T	R	—
Foraminifers	R	C	R	C	C
Calc. nannofossils	D	D	D	D	A
Radiolarians	T	T	T	T	R

SITE 586 HOLE B CORE 2 CORED INTERVAL 11.0–20.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
N22
N22
N22
N22
N22
N22
NN19
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5GY 7/1
5G 6/1
N8
5G 6/1
5GY 7/1
5GY 7/1
5GY 8/1
5BG 5/1
5BG 5/1
5BG 5/1
5BG 5/1
5BG 7/1
5G 7/1
5GY 7/1
5BG 5/1
N8
5GY 7/1
N8
5G 6/2
5G 6/2
5GY 7/1

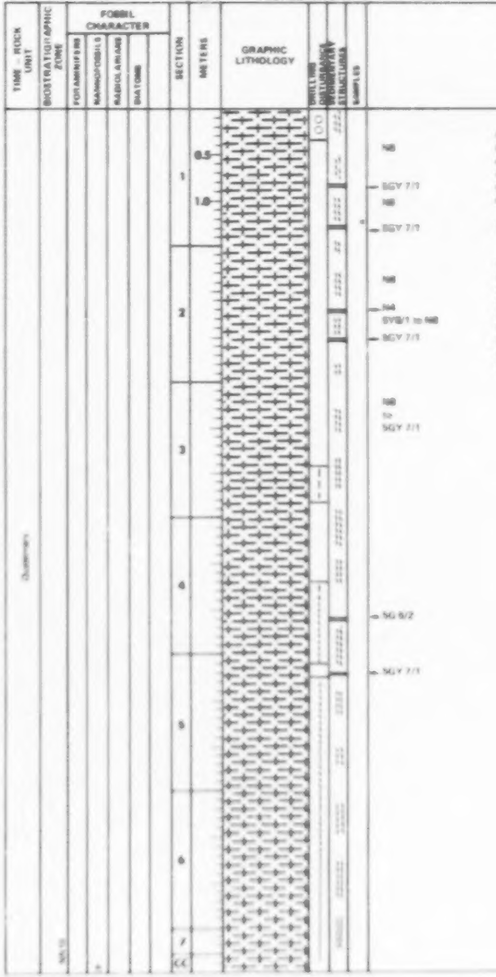
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light greenish gray (5GY 7/1) grading to very light gray (N8) by Section 5, soft lamina of greenish gray (5G 6/1 and 5G 7/1) scattered throughout. Appear to be celadonite(?) from devitrified volcanic ash. Very subtle color cycles. Blebs and streaks of pyrite, greenish gray (5BG 5/1) scattered throughout. Faint burrow mottling common. Eight mm diameter nodule at Section 5, 8 cm.

SMEAR SLIDE SUMMARY

	2, 98 D	6, 17 M	6, 118 D
Texture:			
Sand	—	R	C
Silt	C	A	C
Clay	D	A	D
Composition:			
Mica	—	—	T
Volcanic glass	—	—	T
Foraminifers	C	A	C
Calc. nannofossils	D	A	D
Radiolarians	T	T	R
Sponge spicules	T	T	—

SITE 586 HOLE B CORE 3 CORED INTERVAL 20.6–30.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 7/1
N8
5GY 7/1
N8
N4
5Y8/1 to N8
5GY 7/1
N8
to
5GY 7/1
5G 6/2
5GY 7/1

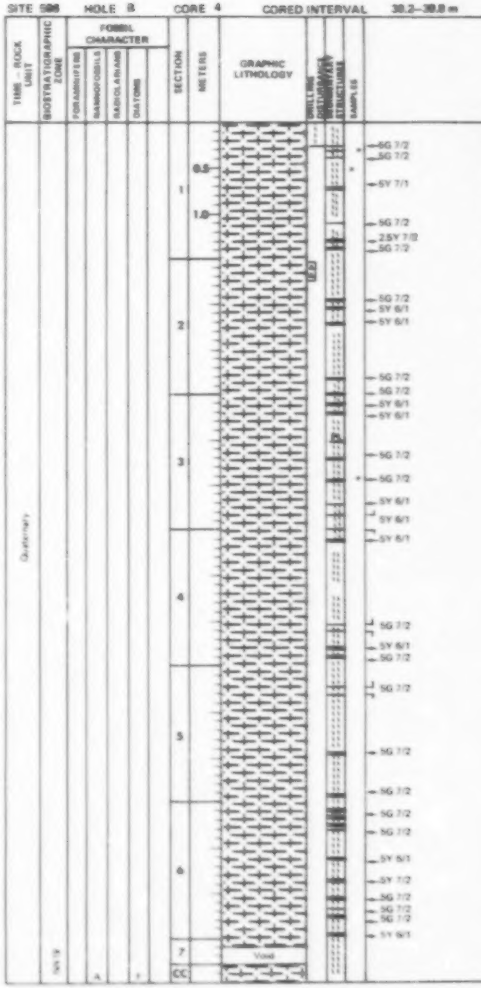
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8) grading to light greenish gray (5GY 7/1), soft, lamina of light greenish gray (5GY 7/1) common, blebs and streaks of pyrite(?) dark gray (N4) common. Subtle laminae of yellowish gray (5Y 8/1) common. Badly disturbed by drilling below mid-Section 4.

SMEAR SLIDE SUMMARY

	1, 122
	D
Texture:	
Silt	A
Clay	A
Composition:	
Mica	T
Foraminifers	A
Calc. nannofossils	A
Diatoms	T
Radiolarians	R

SITE 586 HOLE B CORE 4 CORED INTERVAL 30.2–39.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
5G 7/2
5G 7/2
5Y 7/1
5G 7/2
2.5Y 7/2
5G 7/2
5G 7/2
5Y 6/1
5Y 6/1
5G 7/2
5G 7/2
5Y 6/1
5Y 6/1
5G 7/2
5G 7/2
5Y 6/1
5Y 6/1
5Y 6/1
5G 7/2
5Y 6/1
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5Y 6/1
5Y 7/2
5G 7/2
5G 7/2
5G 7/2
5Y 6/1

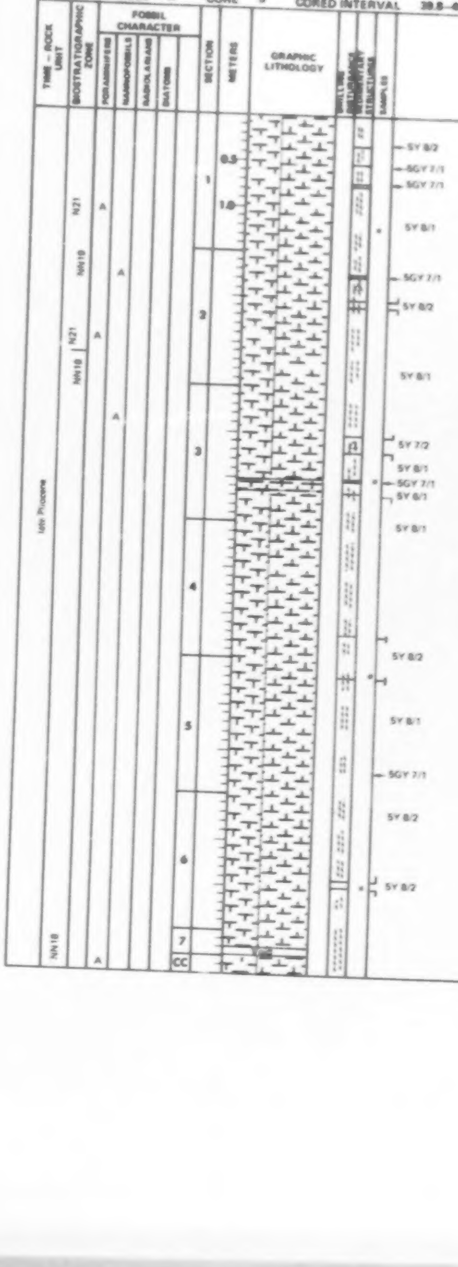
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, light gray (5Y 7/1), soft, with lamina (<1 cm thick) of pale green (5G 7/2) and light gray (5Y 6/1) throughout. Light gray (5Y 6/1) burrow mottles are common. Streaks and blebs of very dark gray (5Y 3/1) pyrite(?) very common. Pale green lamina may be celadonite(?) from devitrified volcanic ash. Graded or winnowed interval occurs at Section 3, 50 cm.

SMEAR SLIDE SUMMARY

	1, 30	1, 50	3, 50
	M	D	M
Texture:			
Sand	–	–	C
Silt	A	A	C
Clay	A	A	A
Composition:			
Mica	–	T	–
Volcanic glass	–	–	T
Pyrite	A	–	–
Foraminifers	T	A	A
Calc. nannofossils	A	A	A
Diatoms	–	T	–
Radiolarians	–	R	R

SITE 586 HOLE B CORE 5 CORED INTERVAL 39.8–49.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
N21
NN19
N21
NN18
NN18
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/2
5GY 7/1
5GY 7/1
5Y 8/1
5GY 7/1
5Y 8/2
5Y 8/1
5Y 7/2
5Y 8/1
5GY 7/1
5Y 6/1
5Y 8/1
5Y 8/2
5Y 8/1
5GY 7/1
5Y 8/2
5Y 8/2

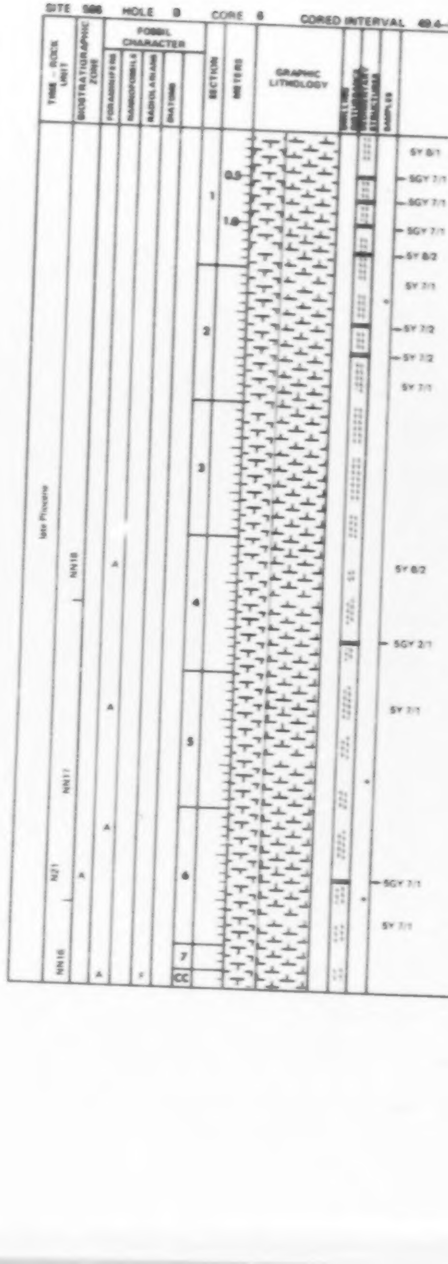
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, yellowish gray (5Y 8/1), soft, with lamina of light greenish gray (5GY 7/1) of celadonite(?) from devitrified volcanic ash. Burrow mottling of dark gray (N4) abundant throughout. Graded or winnowed interbed at Section 2, 50–60 cm and Section 3, 56–70 cm. An interbed of FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1) occurs at Section 3, 102–111 cm. Possibly a winnowed zone. The entire core has subtle color mottles. Streaks and blebs of pyrite(?) commonly occur.

SMEAR SLIDE SUMMARY:

	1, 12 D	3, 100 M	5, 20 M	6, 99 M
Texture:				
Sand	R	R	–	–
Silt	C	A	C	–
Clay	D	A	D	–
Composition:				
Pyrite	–	T	–	–
Foraminifers	C	A	C	R
Calc. nannofossils	D	A	D	D
Diatoms	–	T	–	–
Radiolarians	T	T	T	T
Sponge spicules	T	T	–	T
Silicoflagellates	–	–	–	T

SITE 586 HOLE B CORE 6 CORED INTERVAL 49.4–59.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN18
NN17
N21
NN16
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
5GY 7/1
5GY 7/1
5GY 7/1
5Y 8/2
5Y 7/1
5Y 7/2
5Y 7/2
5Y 7/1
5Y 8/2
5GY 2/1
5Y 7/1
5GY 7/1
5Y 7/1

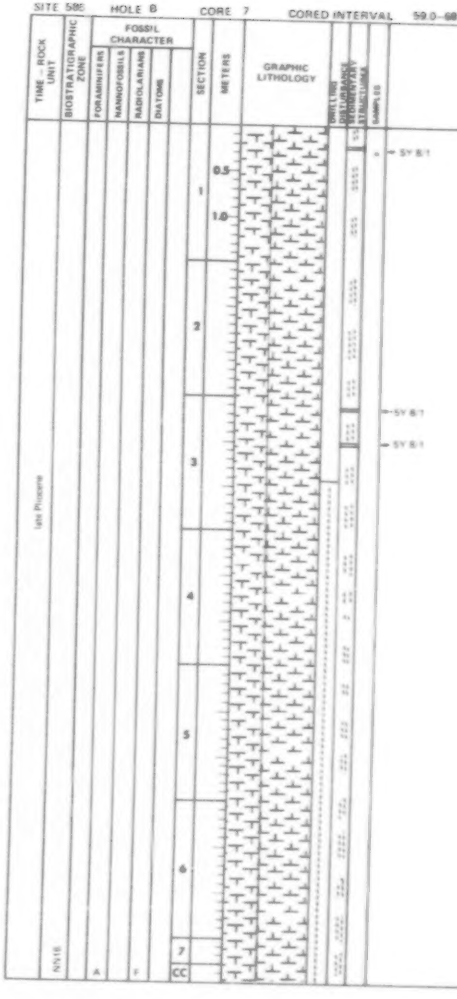
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, yellowish gray (5Y 8/1), soft, with lamina of light greenish gray (5GY 7/1 to 5GY 8/2) celadonite(?) of devitrified volcanic ash. Burrow mottling common with subtle color differences. Blebs and streaks of pyrite common.

SMEAR SLIDE SUMMARY:

	2, 31 D	5, 115 D	6, 91 D
Texture:			
Sand	R	R	R
Silt	C	C	C
Clay	D	D	D
Composition:			
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	T	T	T
Sponge spicules	T	–	T

SITE 586 HOLE B CORE 7 CORED INTERVAL 59.0–68.6 m



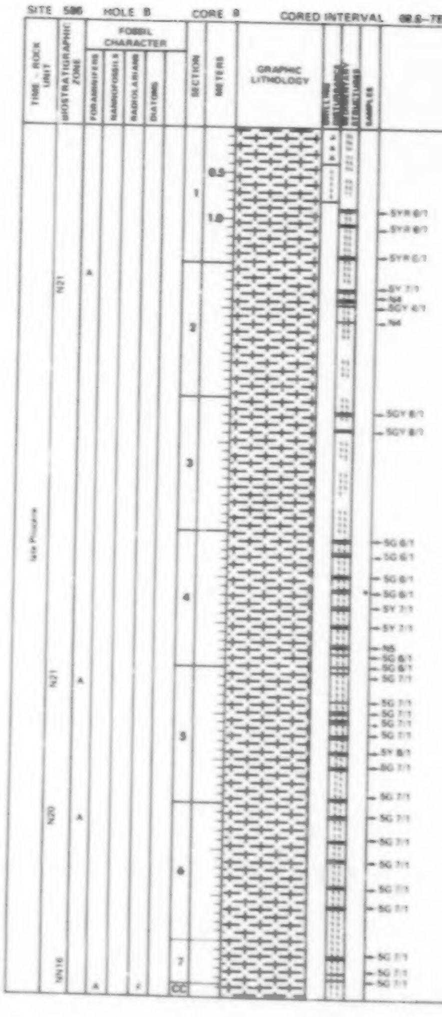
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, burrows, laminae, and thin interbeds (<3 cm) of yellowish gray (5Y 8/1). Medium dark gray (N4) streaks and beds of pyrite(?) common. Entire core appears bioturbated and subtlely laminated. Severe coring disturbance below Section 3, 86 cm.

SMEAR SLIDE SUMMARY:

	1, 29
	D
Texture:	
Sand	–
Silt	C
Clay	D
Composition:	
Volcanic glass	R
Pyrite	T
Foraminifers	C
Calc. nannofossils	A
Diatoms	R
Radiolarians	R

SITE 586 HOLE B CORE 8 CORED INTERVAL 68.6–78.2 m



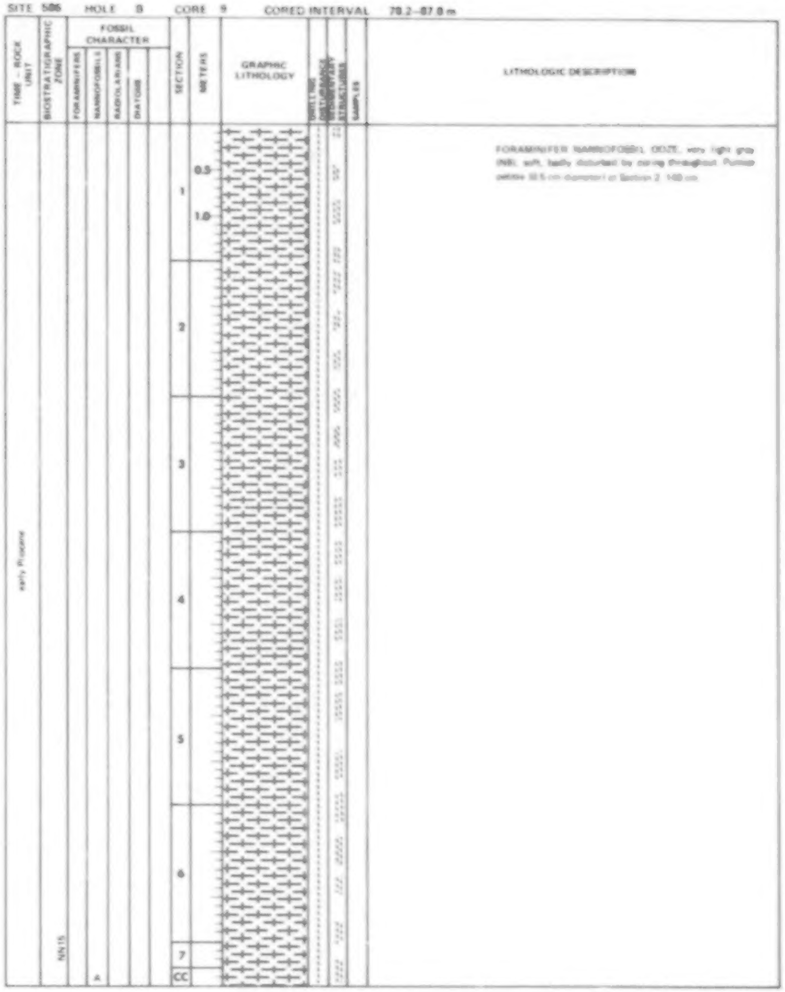
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), soft, with thin laminae and interbeds (< 1 cm thick) of subtle shades of light greenish gray (5GY 8/1) and light brownish gray (5YR 6/1). Burrow mottling subtle but increases in definition with depth. Streaks and beds of pyrite(?) common throughout. Cycles of color occur throughout. Light greenish gray (5G 7/1) layers (< 1 cm thick) of weathered(?) from altered volcanic glass observed in Sections 4, 5, and 6.

SMEAR SLIDE SUMMARY:

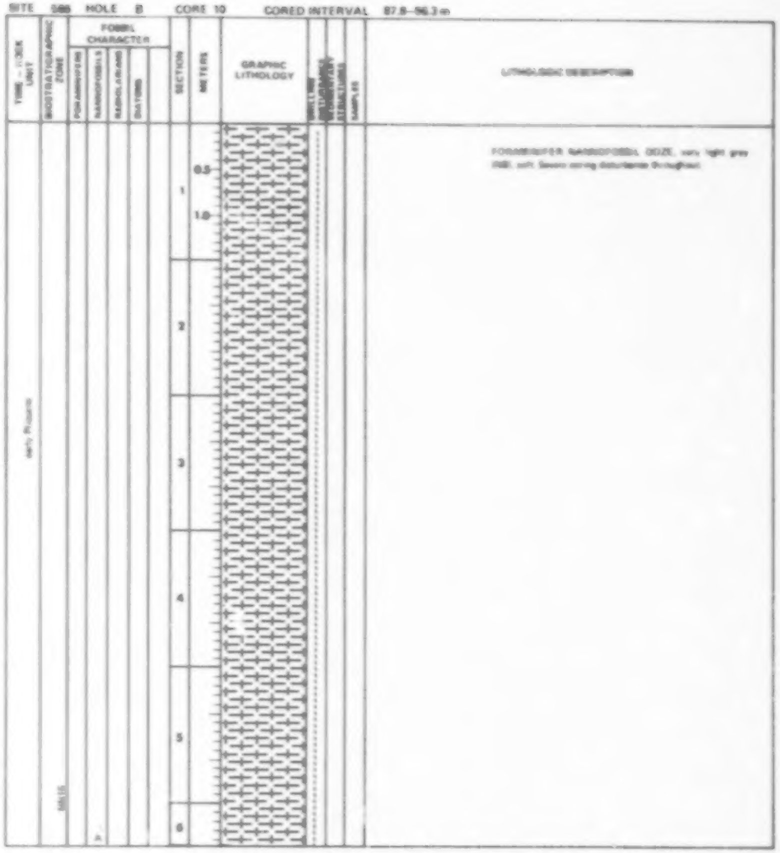
	1, 18
	D
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	A
Calc. nannofossils	A
Radiolarians	R
Sponge spicules	T

SITE 586 HOLE B CORE 9 CORED INTERVAL 78.2–87.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC

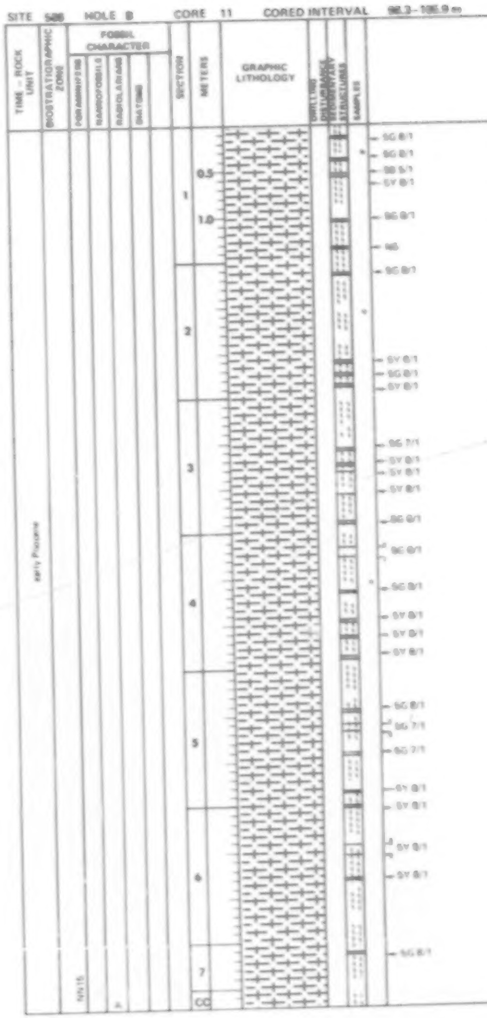
FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), soft, badly disturbed by coring throughout. Pumice pebble (0.5 cm diameter) at Section 2, 140 cm.

SITE 586 HOLE B CORE 10 CORED INTERVAL 87.8–96.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6

FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), soft. Severe coring disturbance throughout.

SITE 586 HOLE B CORE 11 CORED INTERVAL 96.3–105.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
5G 8/1
5G 8/1
5B 5/1
5Y 8/1
5G 8/1
N5
5G 8/1
5Y 8/1
5G 8/1
5Y 8/1
5G 7/1
5Y 8/1
5Y 8/1
5Y 8/1
5G 8/1
5G 8/1
5G 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5G 8/1
5G 7/1
5G 7/1
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5G 8/1

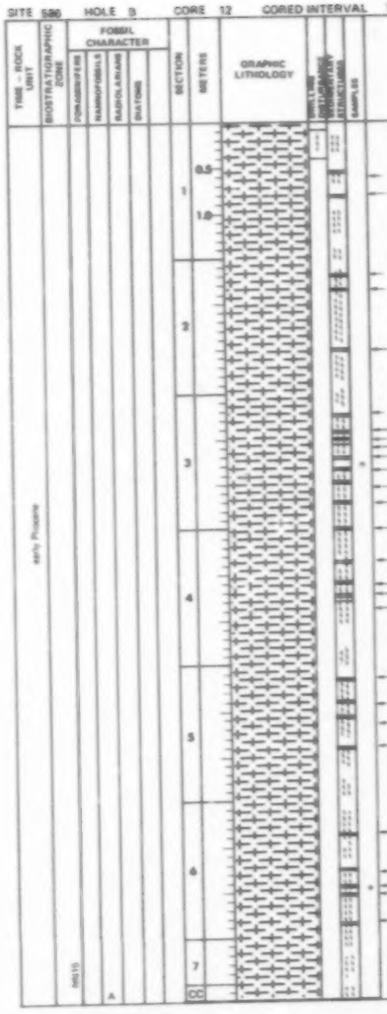
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, light greenish gray (5GY 8/1), soft, with cyclic thin (<1 cm) interbeds of subtle color shades of light greenish gray (5G 8/1), medium bluish gray (5B 5/1), and medium gray (N5). Bioturbation is subtle but apparent. Streaks and blebs of pyrite(?) are common. Light greenish gray (5G 8/1) interbeds may be celadonite(?) from altered volcanic ash.

SMEAR SLIDE SUMMARY

	1, 28	2, 97	3, 114	4, 55
	D	M	M	D
Texture:				
Sand	R	T	—	C
Silt	C	A	—	A
Clay	D	A	—	A
Composition:				
Mica	T	—	—	—
Volcanic glass	R	T	D	—
Pyrite	T	—	—	—
Foraminifers	A	A	A	—
Calc. nannofossils	A	A	A	—
Diatoms	—	—	R	—
Radiolarians	R	T	T	—

SITE 586 HOLE B CORE 12 CORED INTERVAL 105.9–115.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
5Y 8/1
N9
5Y 7/1
5G 8/1

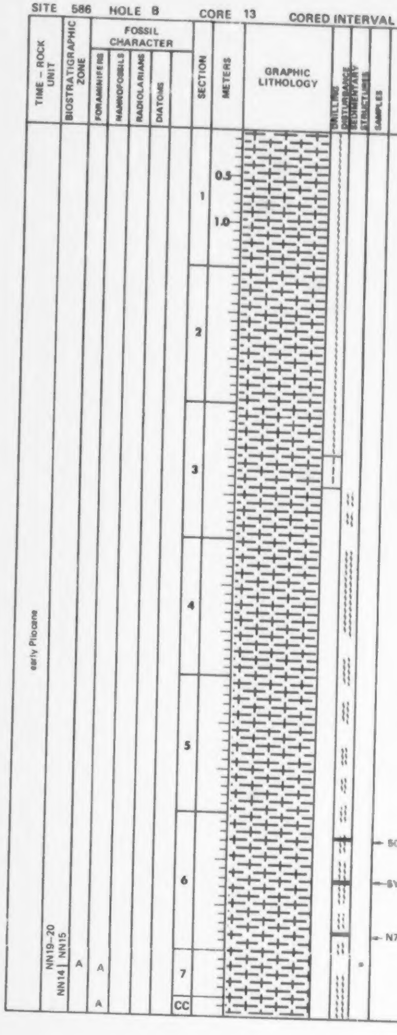
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, white (N9), soft, burrowed, and streaks and blebs of pyrite(?) common throughout. Faint hints of laminae throughout (indicated by "—" on adjacent column).

SMEAR SLIDE SUMMARY

	3, 80	6, 83	7, 18
	D	M	D
Texture:			
Sand	C	—	C
Silt	A	A	A
Clay	A	A	D
Composition:			
Heavy minerals	T	—	—
Foraminifers	A	A	A
Calc. nannofossils	A	A	A
Radiolarians	—	T	T

SITE 586 HOLE B CORE 13 CORED INTERVAL 115.5–125.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN19–20
NN14 | NN15
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/1
5Y 8/1
N7

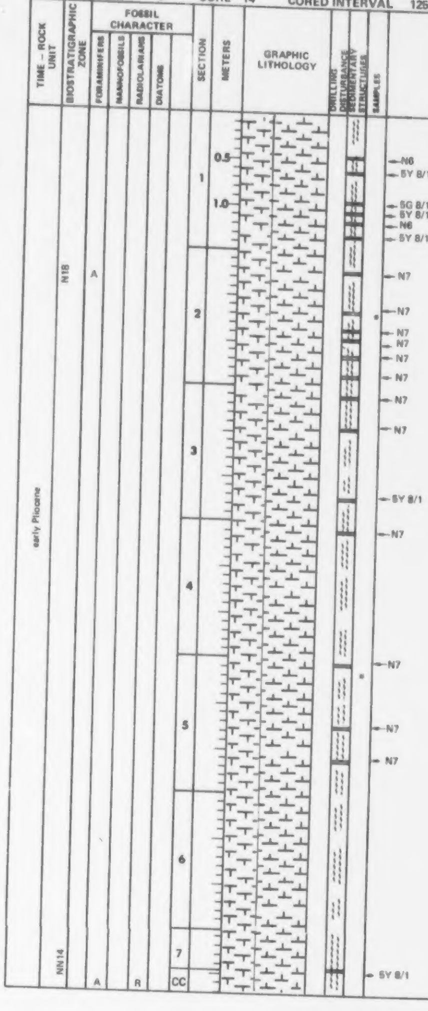
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), firm. Bioturbation very common with yellowish gray (5Y 8/1) mottles. Minor pyrite(?) specks. Very few lamina apparent. Bioturbation appears to increase in intensity with depth. Pyrite(?) increases in occurrence with depth.

SMEAR SLIDE SUMMARY:

	7, 14
	D
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Foraminifers	C
Calc. nannofossils	D
Radiolarians	T

SITE 586 HOLE B CORE 14 CORED INTERVAL 125.1–134.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
N18
NN14
A
A
R
0.5
1.0
1
2
3
4
5
6
7
CC
N6
5Y 8/1
5G 8/1
5Y 8/1
N6
5Y 8/1
N7
N7
N7
N7
N7
N7
N7
N7
5Y 8/1
N7
N7
N7
N7
5Y 8/1

LITHOLOGIC DESCRIPTION

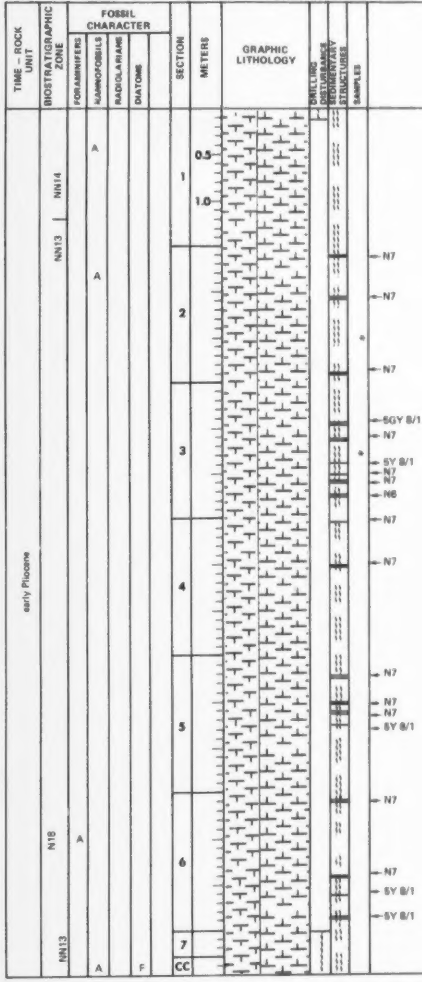
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, intense bioturbation, rind burrows prominant. Laminae of yellowish gray (5Y 8/1) common. Subtle light gray (N7) laminations.

SMEAR SLIDE SUMMARY:

	2, 70	5, 17
	D	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D
Radiolarians	T	T

READEX FICHE
best copy available

SITE 586 HOLE B CORE 15 CORED INTERVAL 134.7–144.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN14
NN13
N18
NN13
A
A
A
A
F
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N7
N7
5GY 8/1
N7
5Y 8/1
N7
N7
N6
N7
N7
N7
N7
N7
5Y 8/1
N7
N7
5Y 8/1
5Y 8/1

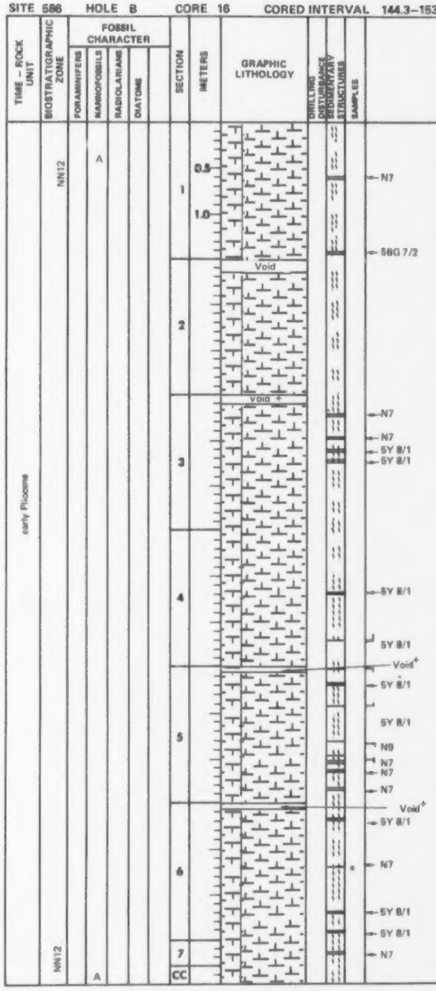
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, abundant yellowish gray (5Y 8/1) mottles, pryite(?) blebs and streaks abundant. Faint laminae of light gray (N7). Rind burrows common.

SMEAR SLIDE SUMMARY:

	2, 110	3, 77
	D	M
Texture:		
Sand	–	–
Silt	C	–
Clay	A	–
Composition:		
Foraminifers	C	C
Calc. nannofossils	A	A
Diatoms	–	T
Radiolarians	T	T

SITE 586 HOLE B CORE 16 CORED INTERVAL 144.3–153.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN12
NN12
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
Void +
N7
5BG 7/2
N7
N7
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
Void+
5Y 8/1
5Y 8/1
N9
N7
N7
N7
Void+
5Y 8/1
N7
5Y 8/1
5Y 8/1
N7

LITHOLOGIC DESCRIPTION

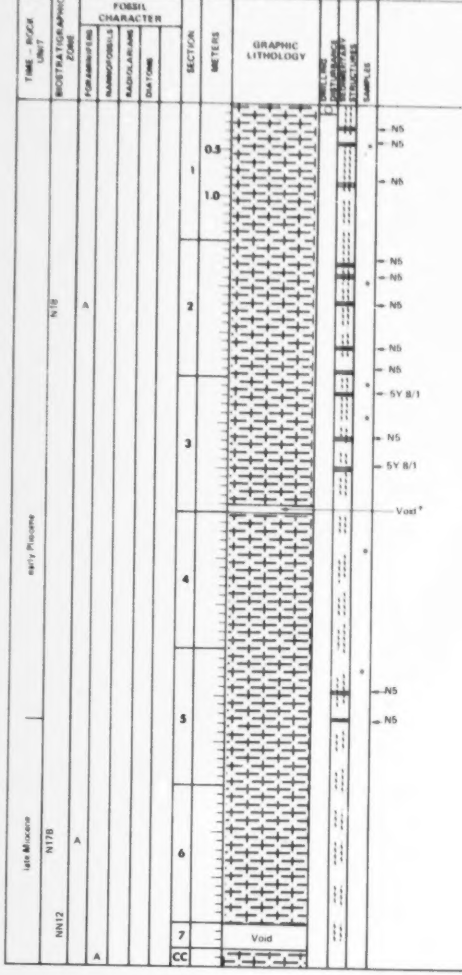
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) grading to white (N9) in Section 2 grading to yellowish gray (5Y 8/1) in Section 3 to white (N9) in Section 6, firm, intensely bioturbated throughout, pyrite(?) blebs and streaks common. Light gray (N7) laminae common in Section 5.

+Note: Artificial void due to excessive core handling. No sediment is missing; sediment has been compressed.

SMEAR SLIDE SUMMARY:

	6, 62
	D
Composition:	
Pyrite	T
Foraminifers	C
Calc. nannofossils	A
Radiolarians	T
Sponge spicules	T

SITE 586 HOLE B CORE 17 CORED INTERVAL 153.9–163.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
N18
N17B
NN12
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N5
N5
N5
N5
N5
N5
N5
N5
5Y 8/1
N5
5Y 8/1
Void*
N5
N5

LITHOLOGIC DESCRIPTION

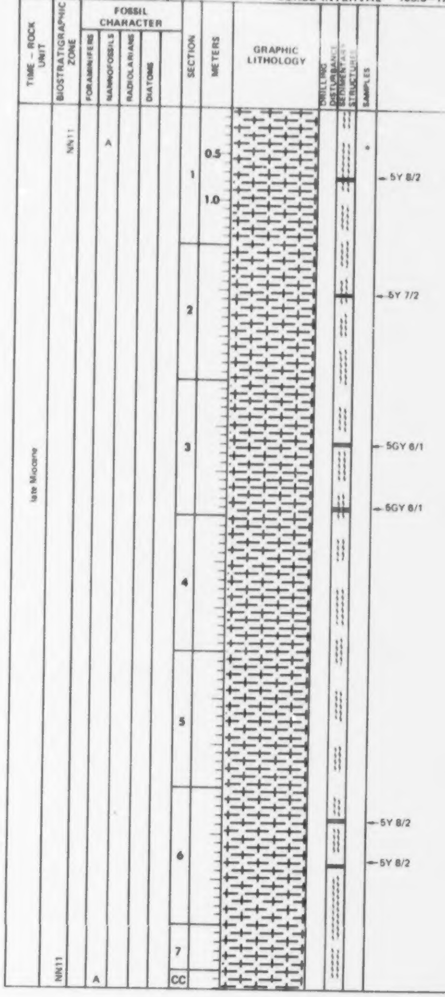
FORAMINIFER NANNOFOSSIL OOZE AND FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm. Bioturbation common throughout, laminations of medium gray (N5) and abundant mottles of yellowish gray (5Y 8/1).

*Note: Void due to excessive core handling: sediment compressed.

SMEAR SLIDE SUMMARY

	1, 45	2, 45	3, 8	3, 45	4, 45	5, 24
	D	D	M	D	D	M
Texture:						
Sand	R	–	C	–	–	C
Silt	A	R	A	A	A	A
Clay	A	D	A	A	A	C
Composition:						
Heavy minerals	T	–	–	–	–	–
Pyrite	–	–	–	–	–	T
Foraminifers	A	R	A	A	A	C
Calc. nannofossils	A	D	A	A	A	A
Radiolarians	–	–	–	T	T	T
Sponge spicules	T	–	T	–	T	T

SITE 586 HOLE B CORE 18 CORED INTERVAL 163.5–173.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
NN11
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/2
5Y 7/2
5GY 6/1
5GY 6/1
5Y 8/2
5Y 8/2

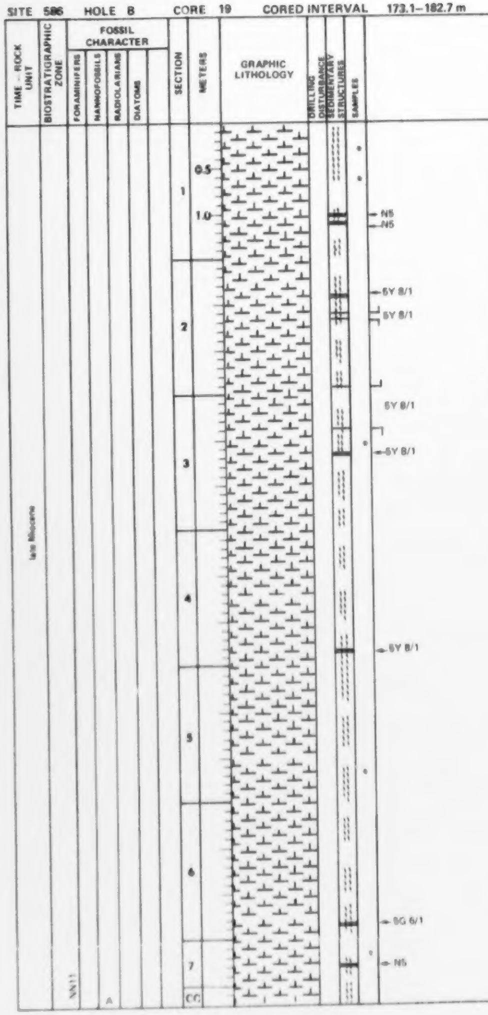
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE and FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), soft, intense bioturbation. Very faint laminae of medium gray (N5) occurs throughout core. Burrows of yellowish gray (5Y 8/2) abundant. Greenish gray (5GY 6/1) laminae occurs in Section 3.

SMEAR SLIDE SUMMARY:

	1, 36	3, 126	4, 147	6, 74
	D	M	M	D
Texture:				
Sand	–	–	–	–
Silt	C	C	C	–
Clay	D	D	D	–
Composition:				
Pyrite	–	T	–	–
Foraminifers	C	C	C	A
Calc. nannofossils	D	D	D	A
Diatoms	–	T	–	–
Radiolarians	T	T	T	T
Sponge spicules	–	T	–	T

SITE 586 HOLE B CORE 19 CORED INTERVAL 173.1–182.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
A
1
2
3
4
5
6
7
CC
0.5
1.0
N5
N5
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5G 6/1
N5

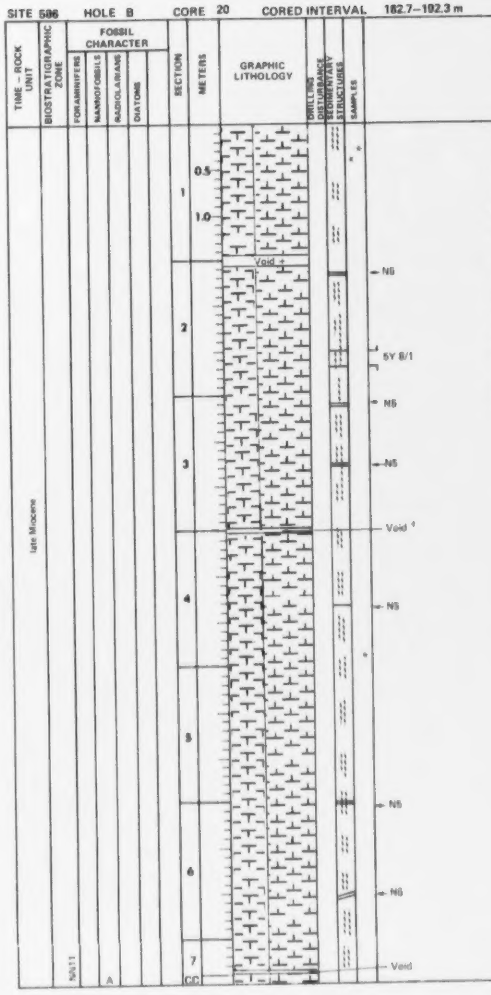
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft. Burrow mottled with specks, blebs, and streaks of yellowish gray (5Y 8/1) and medium gray (N5). Pyrite(?) common. Concentration of spicule-bearing interbeds at Section 3, 59–62 cm.

SMEAR SLIDE SUMMARY:

	1, 13 D	1, 29 M	1, 65 D	3, 61 M	5, 118 D
Texture:					
Sand	–	–	–	–	–
Silt	C	C	–	C	C
Clay	D	D	–	D	D
Composition:					
Volcanic glass	–	–	–	–	T
Pyrite	–	T	–	–	–
Foraminifers	C	C	C	C	C
Calc. nannofossils	D	D	D	D	D
Radiolarians	T	–	–	T	–
Sponge spicules	–	–	T	C	–

SITE 586 HOLE B CORE 20 CORED INTERVAL 182.7–192.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void +
N5
5Y 8/1
N5
N5
Void +
N5
N5
N6
Void

LITHOLOGIC DESCRIPTION

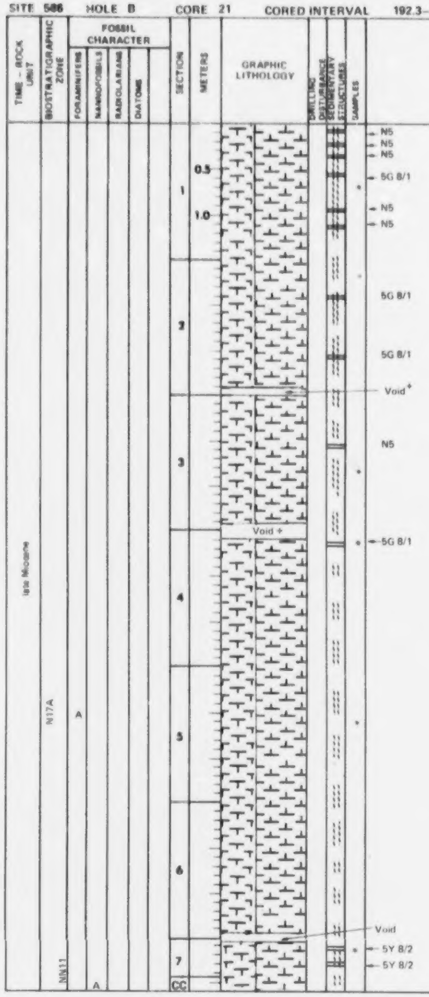
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, burrow-mottled with streaks, blebs and spots of yellowish gray (5Y 8/1) and medium gray (N5) ooze with diffuse boundaries into host ooze.

+ Note: Artifical void due to handling.

SMEAR SLIDE SUMMARY:

	1, 30 M	1, 43 D	4, 143 M
Texture:			
Sand	R	–	R
Silt	C	C	C
Clay	D	D	D
Composition:			
Glauconite	T	–	–
Pyrite	–	–	C
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	T	–	–
Sponge spicules	T	–	–

SITE 586 HOLE B CORE 21 CORED INTERVAL 192.3–201.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N17A
NN11
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void +
N5
N5
N5
5G 8/1
N5
N5
5G 8/1
5G 8/1
Void+
N5
5G 8/1
Void
5Y 8/2
5Y 8/2

LITHOLOGIC DESCRIPTION

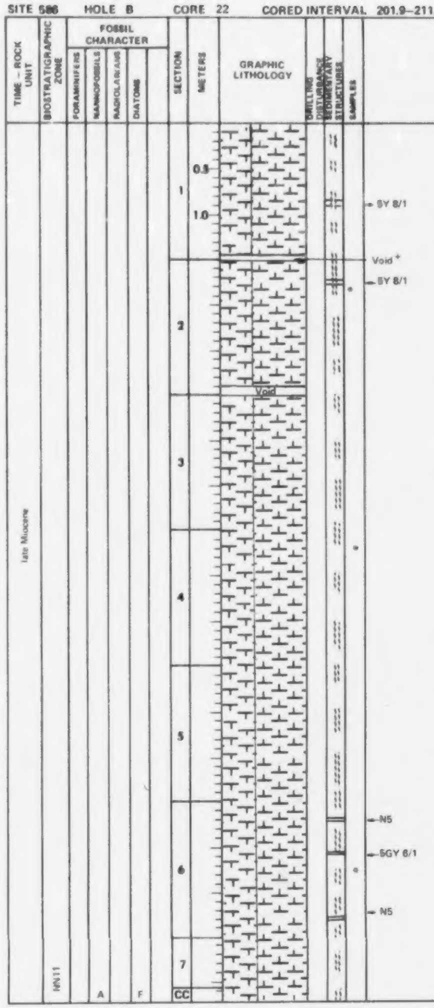
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8) with gray (N5) ooze seems and lamina and light greenish gray (5GY 8/1) burrows.

+Note: Void due to handling.

SMEAR SLIDE SUMMARY:

	1, 68 D	7, 25 M	3, 85 M	4, 10 M	5, 67 –
Texture:					
Sand	–	–	–	–	–
Silt	C	–	A	–	–
Clay	D	–	A	–	–
Composition:					
Heavy minerals	T	T	T	–	–
Pyrite	–	T	T	–	–
Foraminifers	C	A	A	–	C
Calc. nannofossils	D	D	D	–	D
Radiolarians	–	T	–	–	–
Sponge spicules	T	T	T	–	T

SITE 586 HOLE B CORE 22 CORED INTERVAL 201.9–211.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
A
F
0.5
1.0
1
2
3
4
5
6
7
CC
Void
5Y 8/1
Void +
5Y 8/1
N5
5GY 8/1
N5

LITHOLOGIC DESCRIPTION

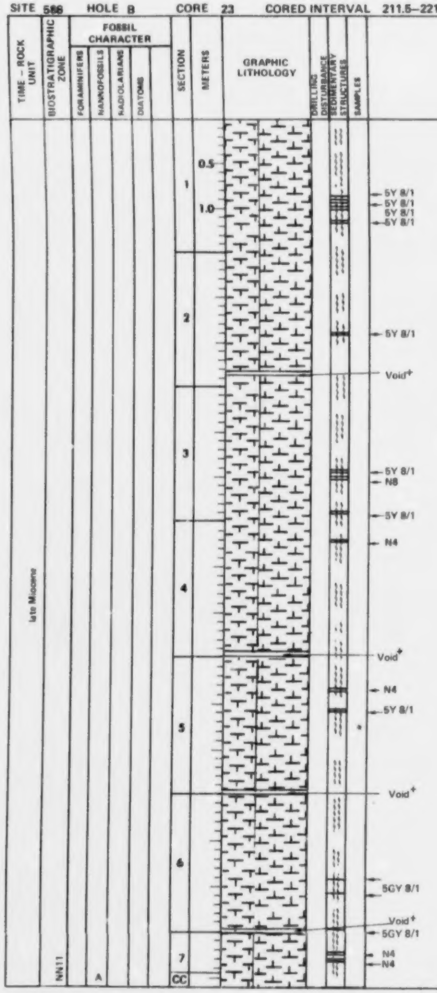
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, burrow-mottled common throughout core.

+Note: Void due to handling.

SMEAR SLIDE SUMMARY:

	2, 38 M	4, 28 D	6, 75 M
Texture:			
Sand	–	–	–
Silt	C	C	C
Clay	D	D	D
Composition:			
Pyrite	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	–	T	T
Sponge spicules	–	–	T

SITE 586 HOLE B CORE 23 CORED INTERVAL 211.5–221.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
Void+
5Y 8/1
N8
5Y 8/1
N4
Void+
N4
5Y 8/1
Void+
5GY 8/1
Void+
5GY 8/1
N4
N4

LITHOLOGIC DESCRIPTION

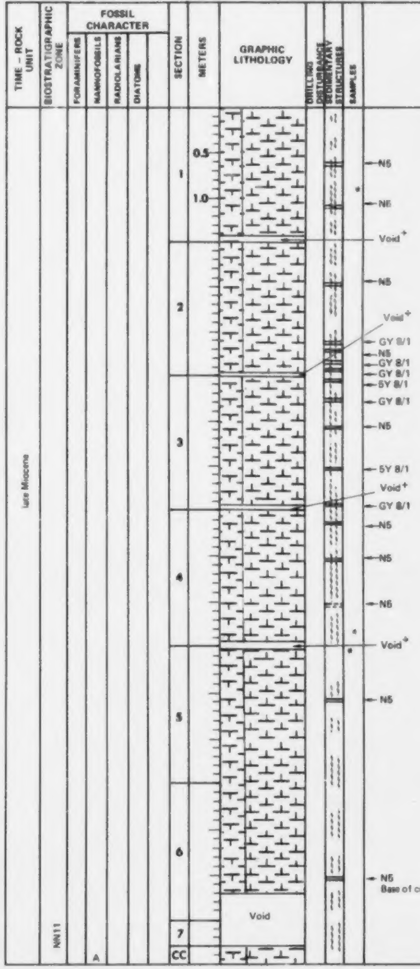
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft burrow-mottled, gradational contacts between colors.

+ Note: Void due to handling.

SMEAR SLIDE SUMMARY:

	5, 78
	D
Texture:	
Sand	–
Silt	C
Clay	D
Composition:	
Quartz	R
Mica	R
Heavy minerals	R
Foraminifers	C
Calc. nannofossils	D
Diatoms	R
Radiolarians	R
Sponge spicules	R

SITE 586 HOLE B CORE 24 CORED INTERVAL 221.1–230.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
A
1
2
3
4
5
6
7
CC
0.5
1.0
N5
N6
Void+
N5
Void+
GY 8/1
N5
GY 8/1
GY 8/1
5Y 8/1
GY 8/1
N5
5Y 8/1
Void+
GY 8/1
N5
N5
N5
Void+
N5
N5
Base of core
Void

LITHOLOGIC DESCRIPTION

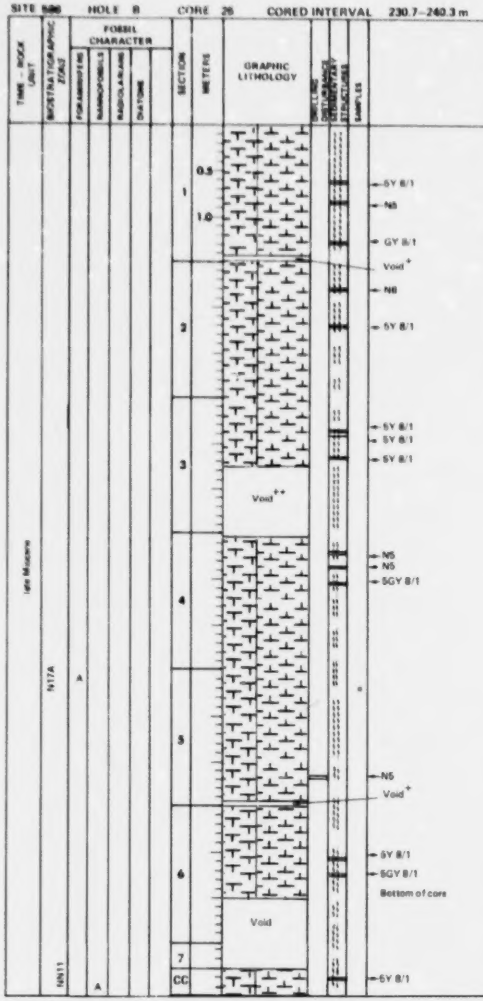
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, with abundant burrows.

+ Note: Void due to handling.

SMEAR SLIDE SUMMARY:

	1, 83	4, 126	5, 9
	D	D	M
Texture:			
Sand	–	–	–
Silt	C	–	–
Clay	D	–	–
Composition:			
Volcanic glass	–	–	T
Pyrite	–	T	–
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	T	T	T
Sponge spicules	T	T	–

SITE 586 HOLE B CORE 26 CORED INTERVAL 230.7–240.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N17A
NN11
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void⁺⁺
Void
5Y 8/1
N5
GY 8/1
Void⁺
N8
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
N5
N5
5GY 8/1
N5
Void⁺
5Y 8/1
5GY 8/1
Bottom of core
5Y 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, abundant burrows and gray (N5) ring bands.

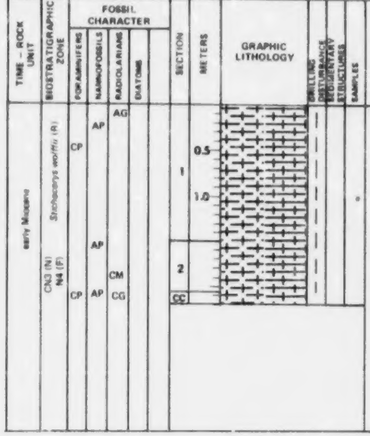
⁺ Note: Void due to handling.

⁺⁺ Note: Void, unidentified cause.

SMEAR SLIDE SUMMARY

	6, 20
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 586 HOLE C CORE 1 CORED INTERVAL 613.5–623.1 m sub-bottom; 2831.5–2841.1 m below rig floor


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
Stichocorys wolffii (R)
CN3 (N)
N4 (F)
CP
AP
AG
AP
CM
CP
AP
CG
1
2
CC
0.5
1.0

LITHOLOGIC DESCRIPTION

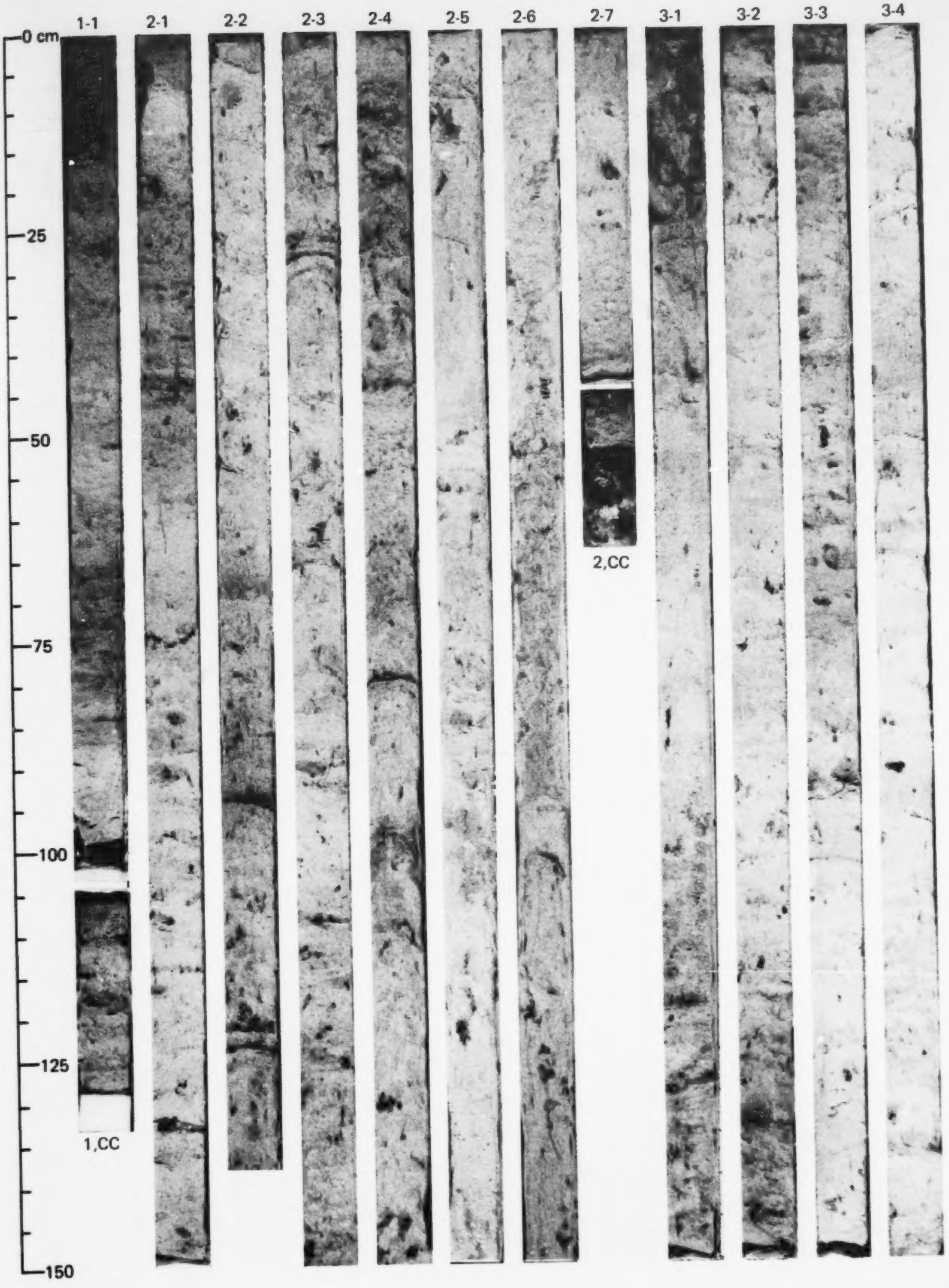
FORAMINIFER-BEARING NANNOFOSSIL OOZE AND MINOR CHALK

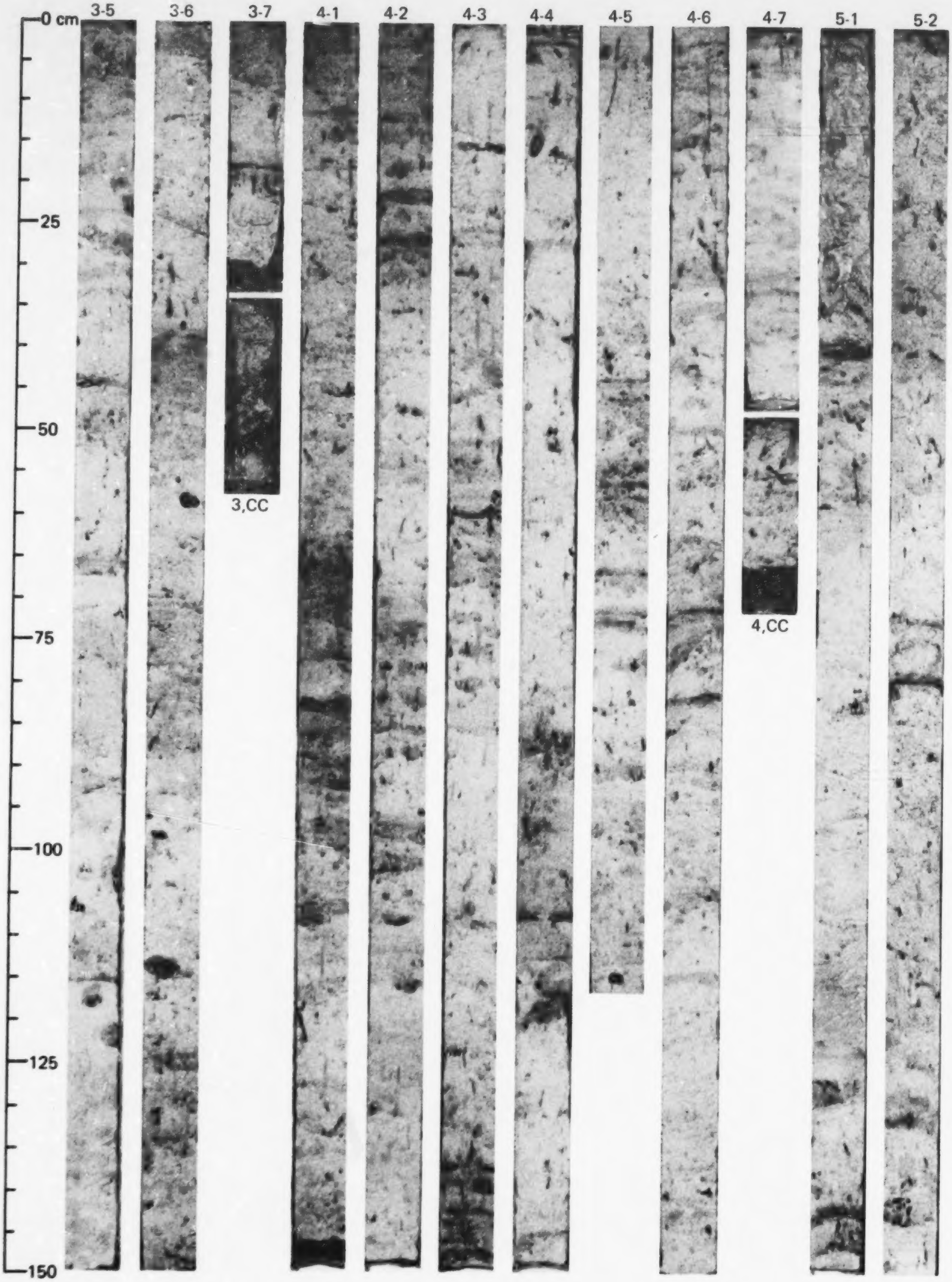
Dominant color is white (N9) to bluish white (5B 9/1) and is homogeneous throughout.

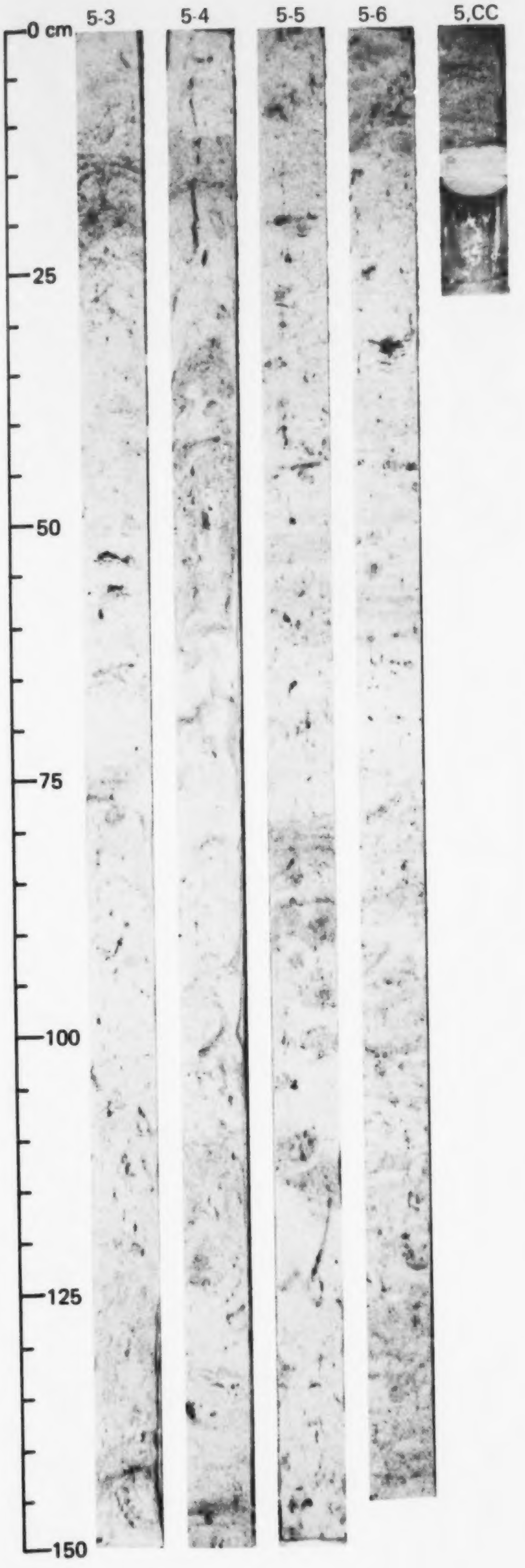
Chalk occurs mainly as nodules and brecciated pieces that undoubtedly were continuous layers that were broken during the drilling process.

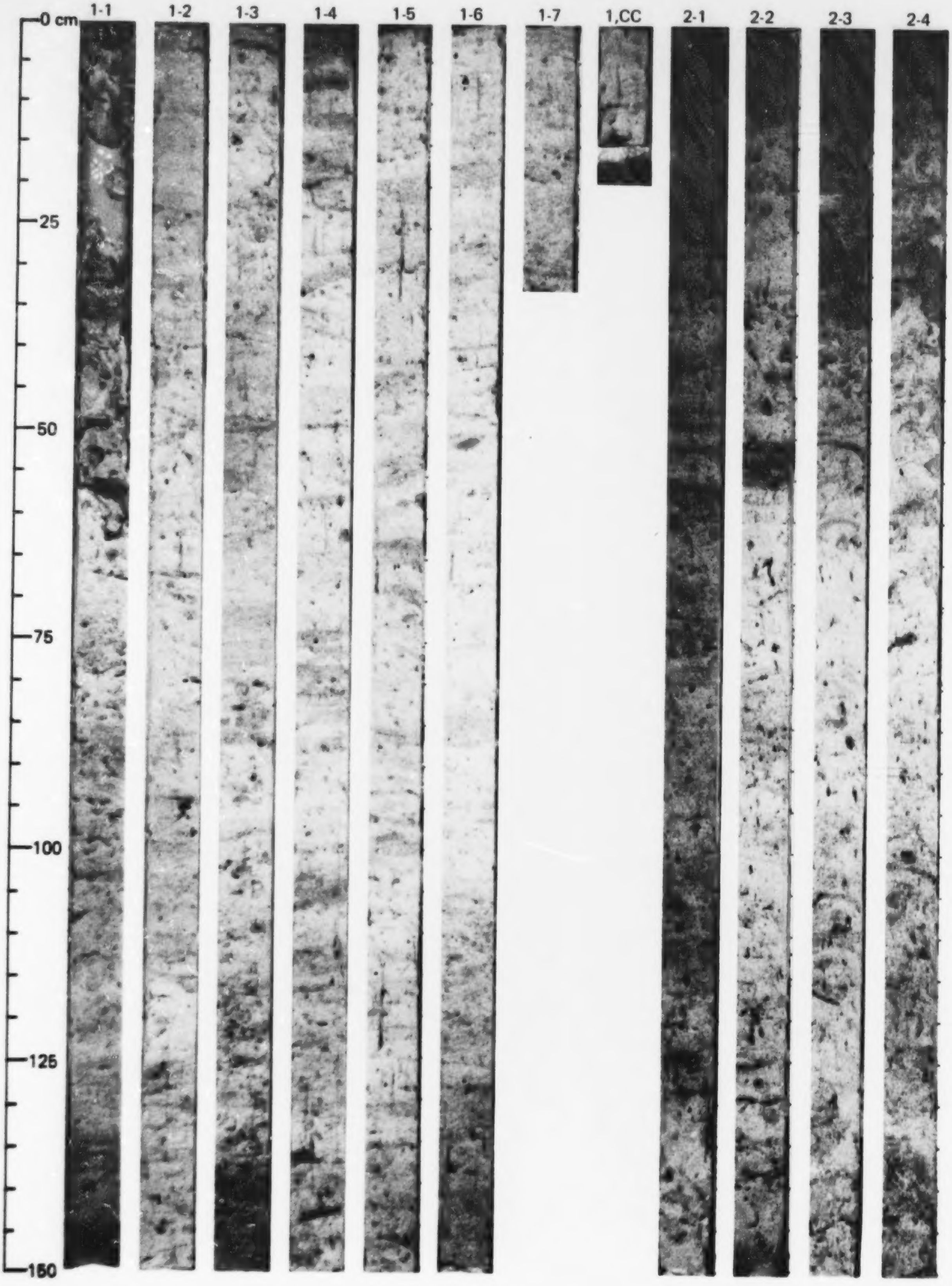
SMEAR SLIDE SUMMARY (%):

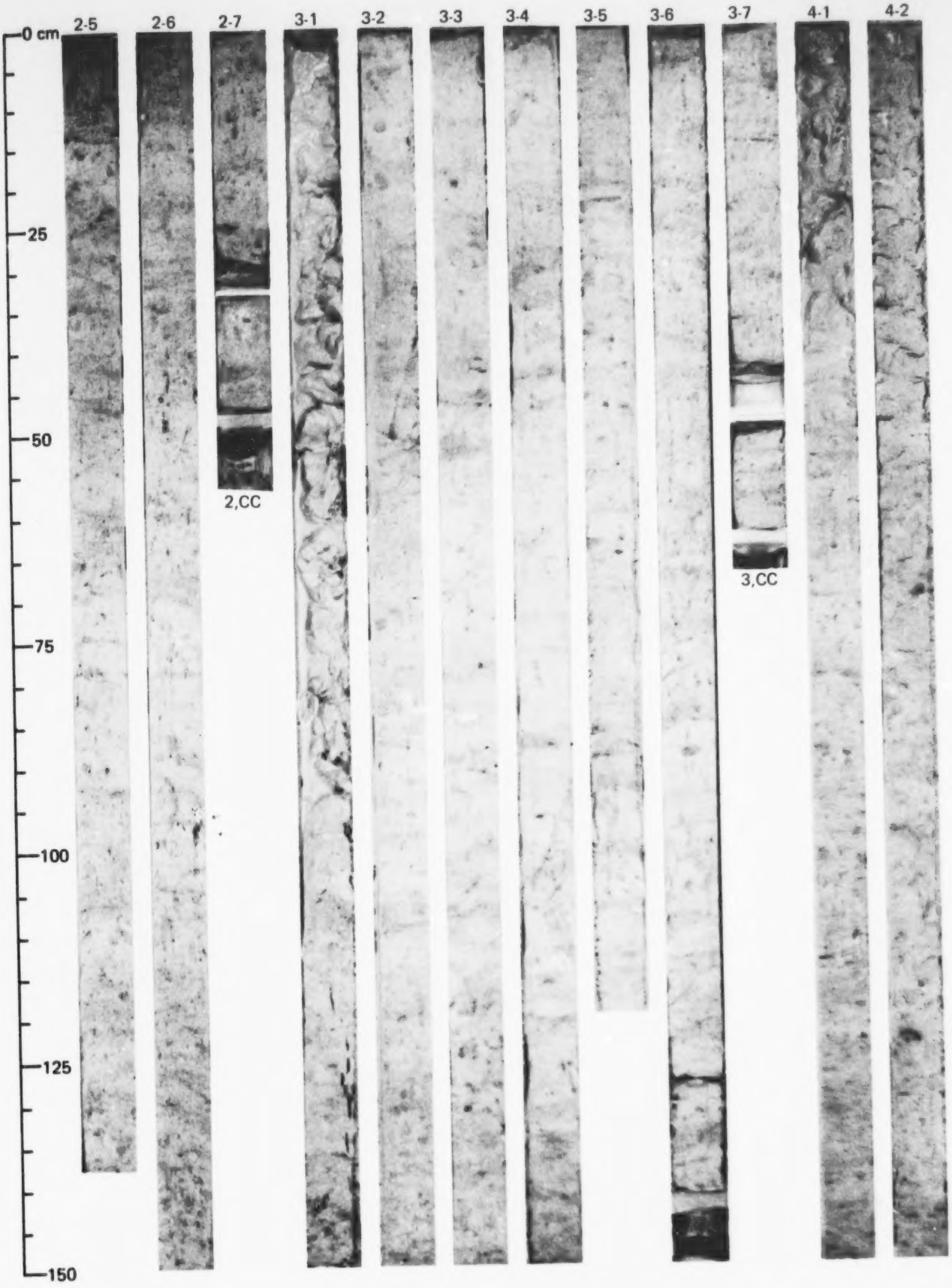
	1, 100
	D
Texture:	
Sand	10
Silt	2
Clay	88
Composition:	
Pyrite	<1
Carbonate unspec.	9
Foraminifers	10
Calc. nannofossils	81
Radiolarians	<1
Sponge spicules	<1

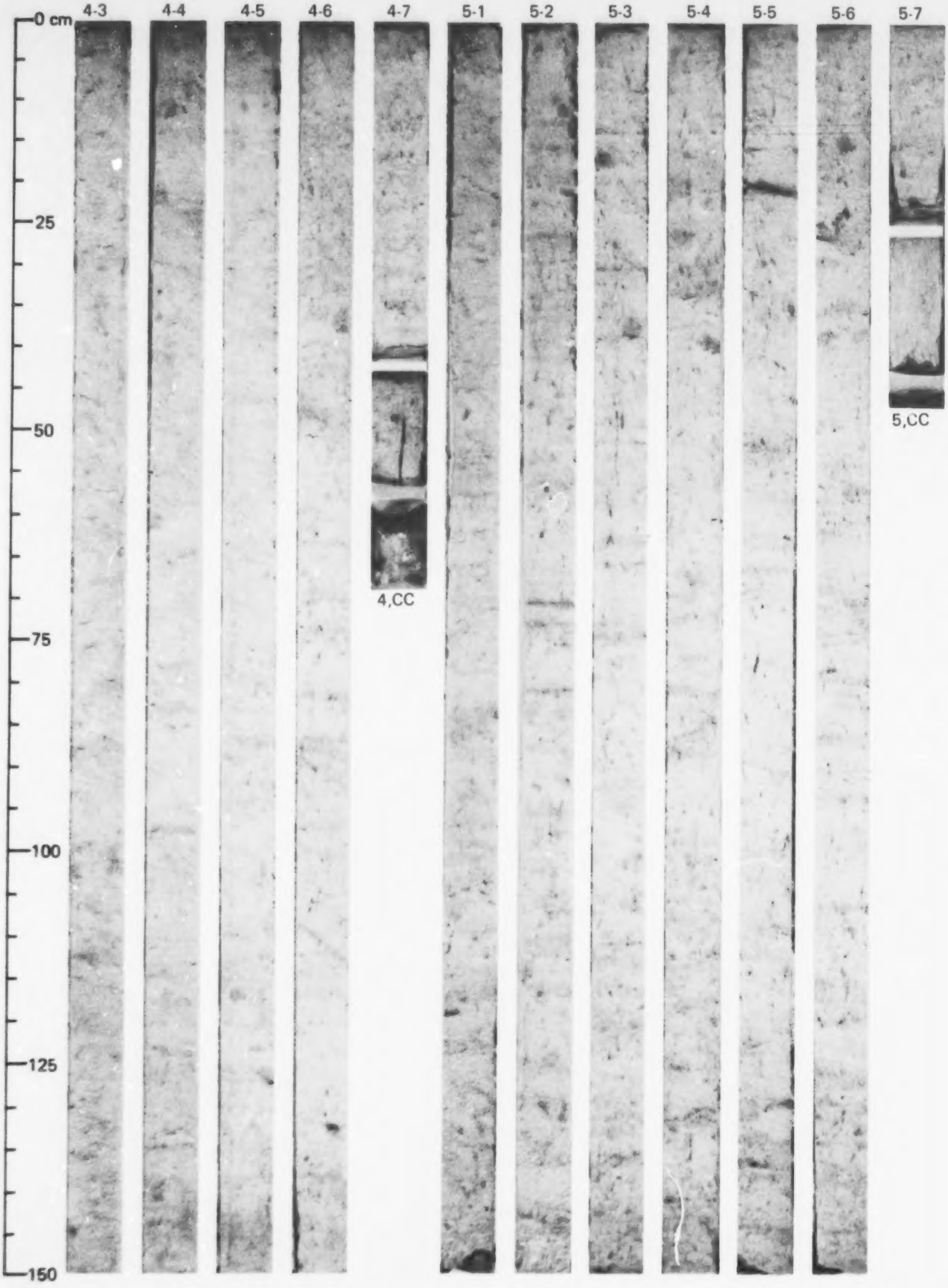

1-1
2-1
2-2
2-3
2-4
2-5
2-6
2-7
3-1
3-2
3-3
3-4
0 cm
25
50
75
100
125
150
1,CC
2,CC


0 cm
25
50
75
100
125
150
3-5
3-6
3-7
4-1
4-2
4-3
4-4
4-5
4-6
4-7
5-1
5-2
3,CC
4,CC

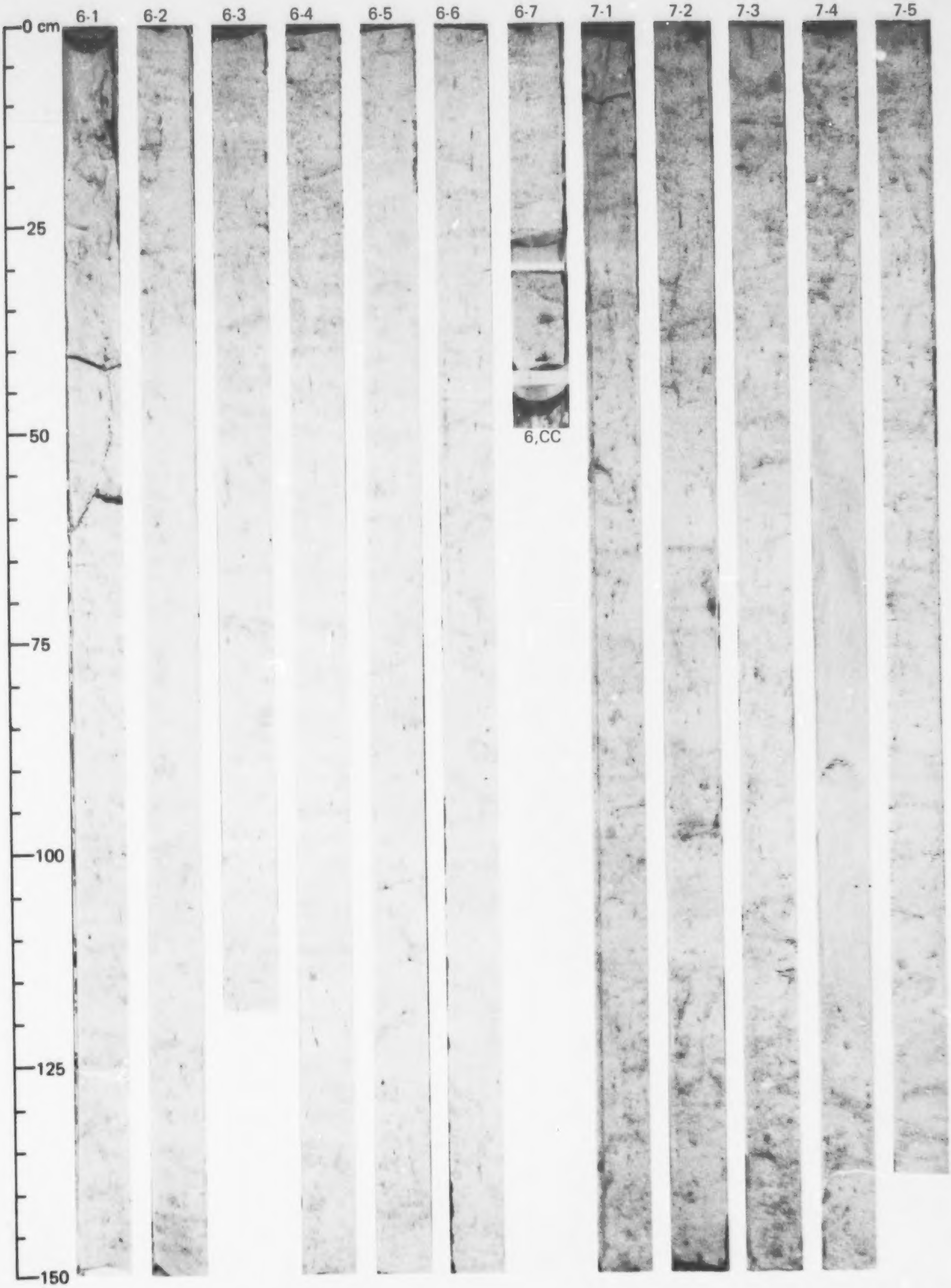

0 cm
25
50
75
100
125
150
5-3
5-4
5-5
5-6
5,CC

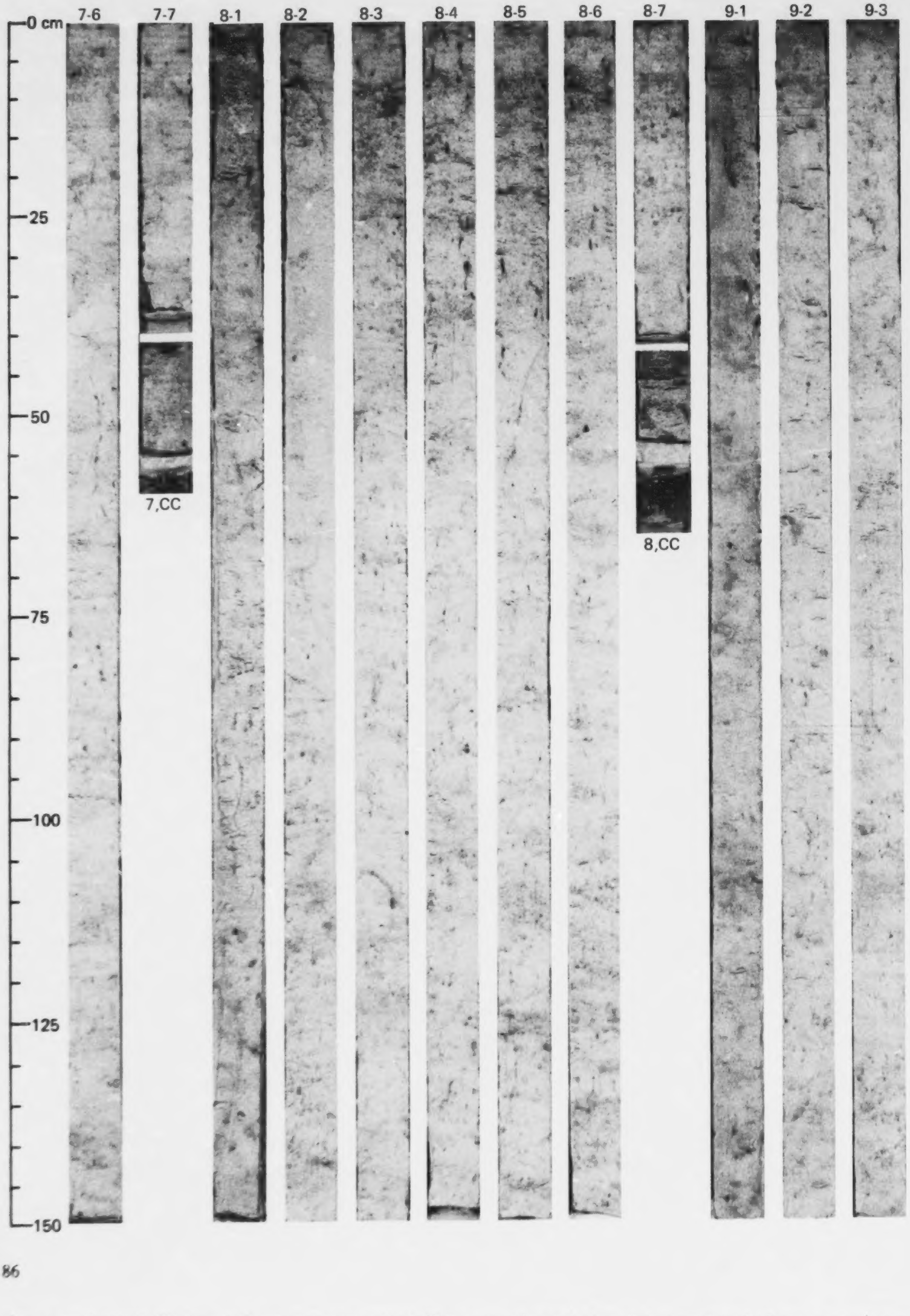

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1,CC
2-1
2-2
2-3
2-4

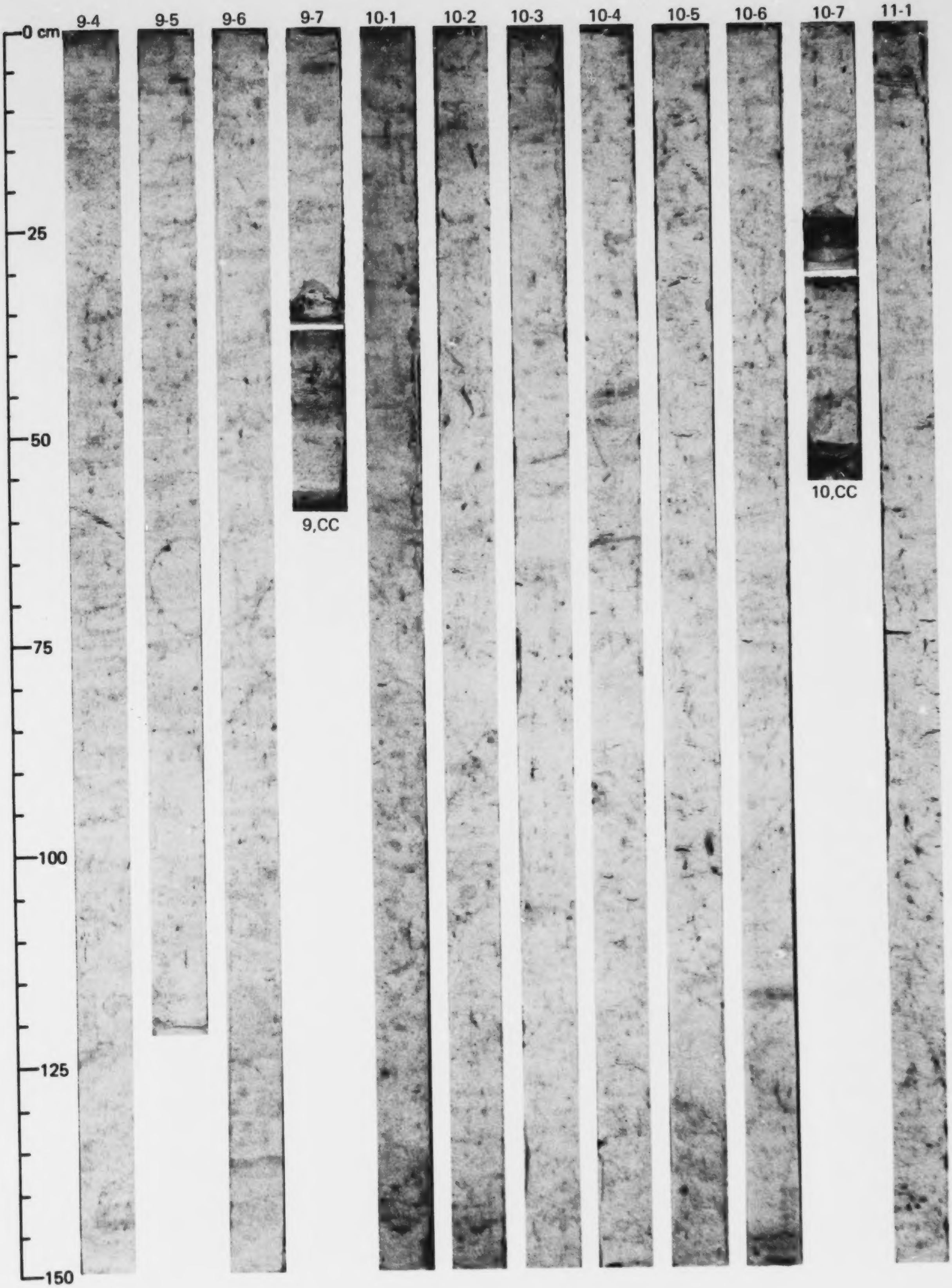

2-5
2-6
2-7
3-1
3-2
3-3
3-4
3-5
3-6
3-7
4-1
4-2
0 cm
25
50
75
100
125
150
2,CC
3,CC

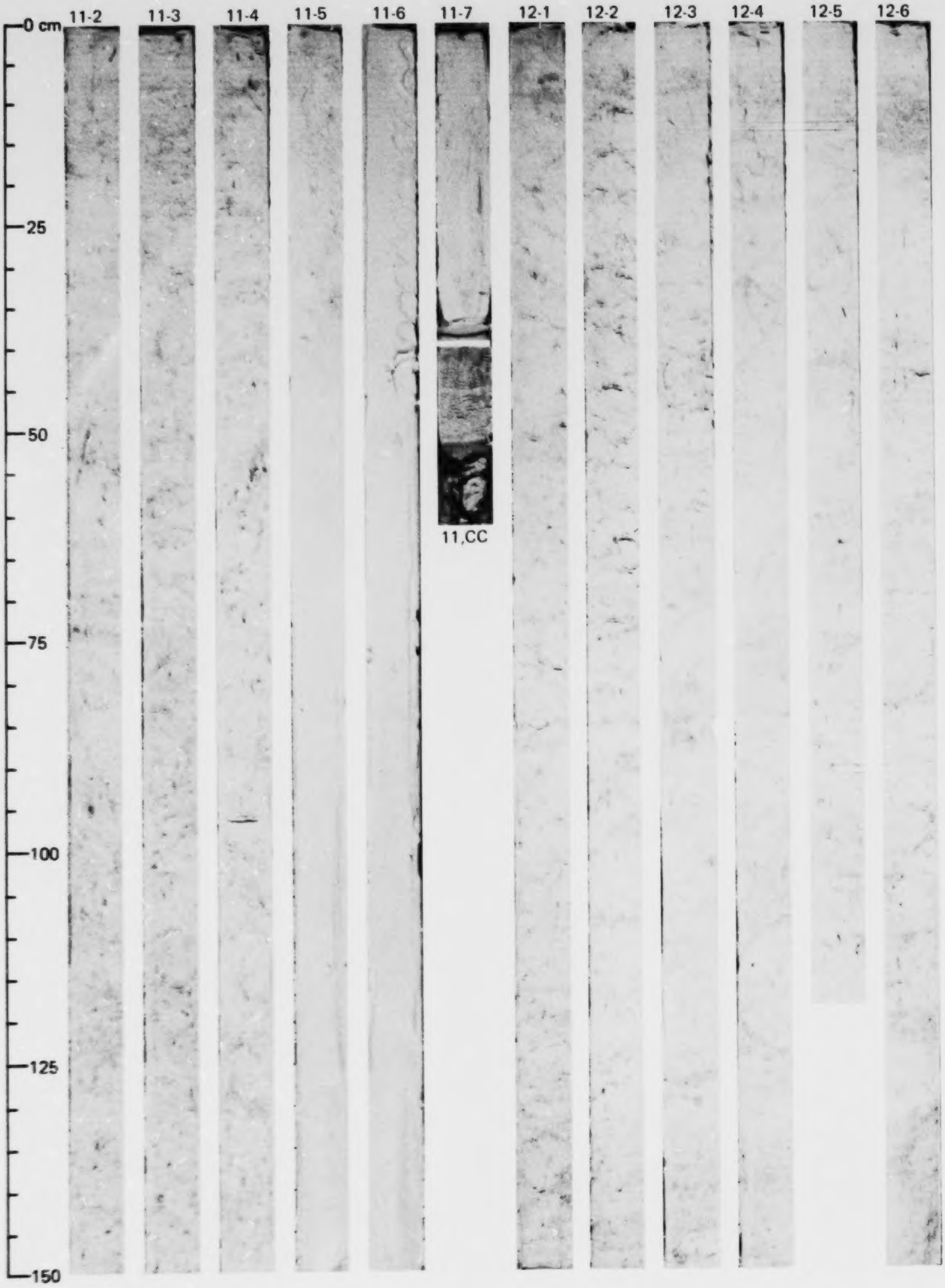


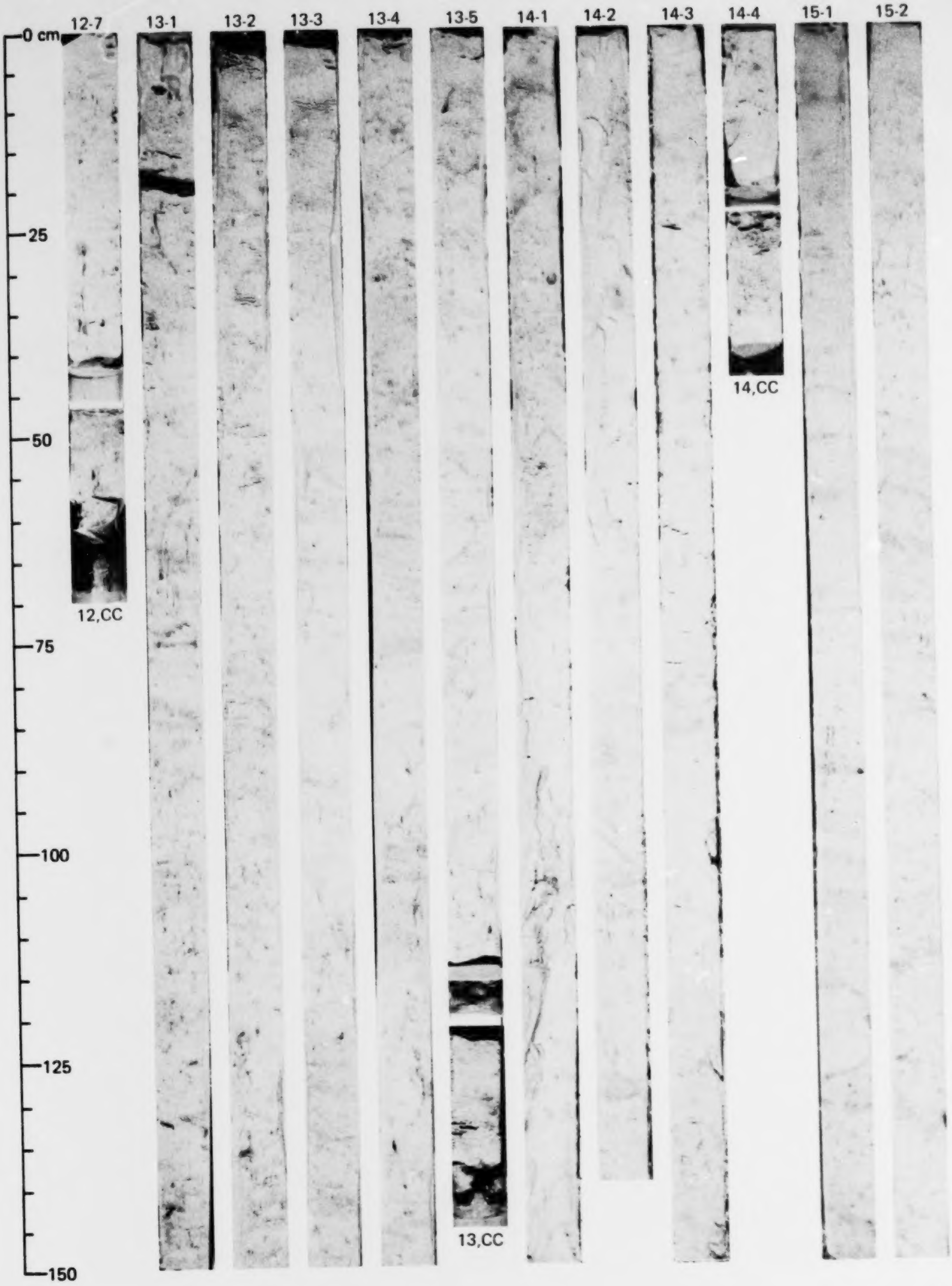
4-3
4-4
4-5
4-6
4-7
5-1
5-2
5-3
5-4
5-5
5-6
5-7
0 cm
25
50
75
100
125
150
4,CC
5,CC

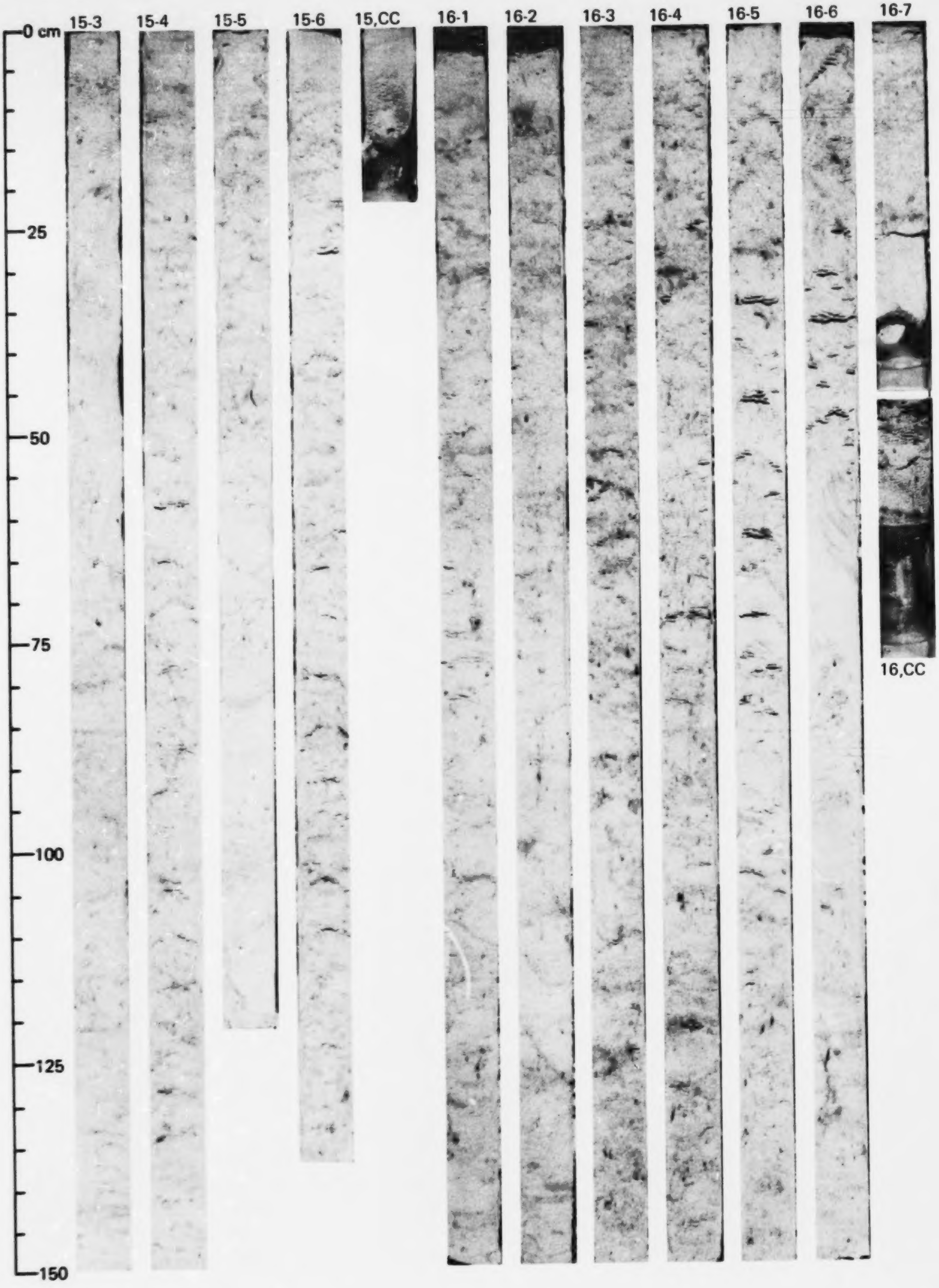

0 cm
25
50
75
100
125
150
6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4
7-5

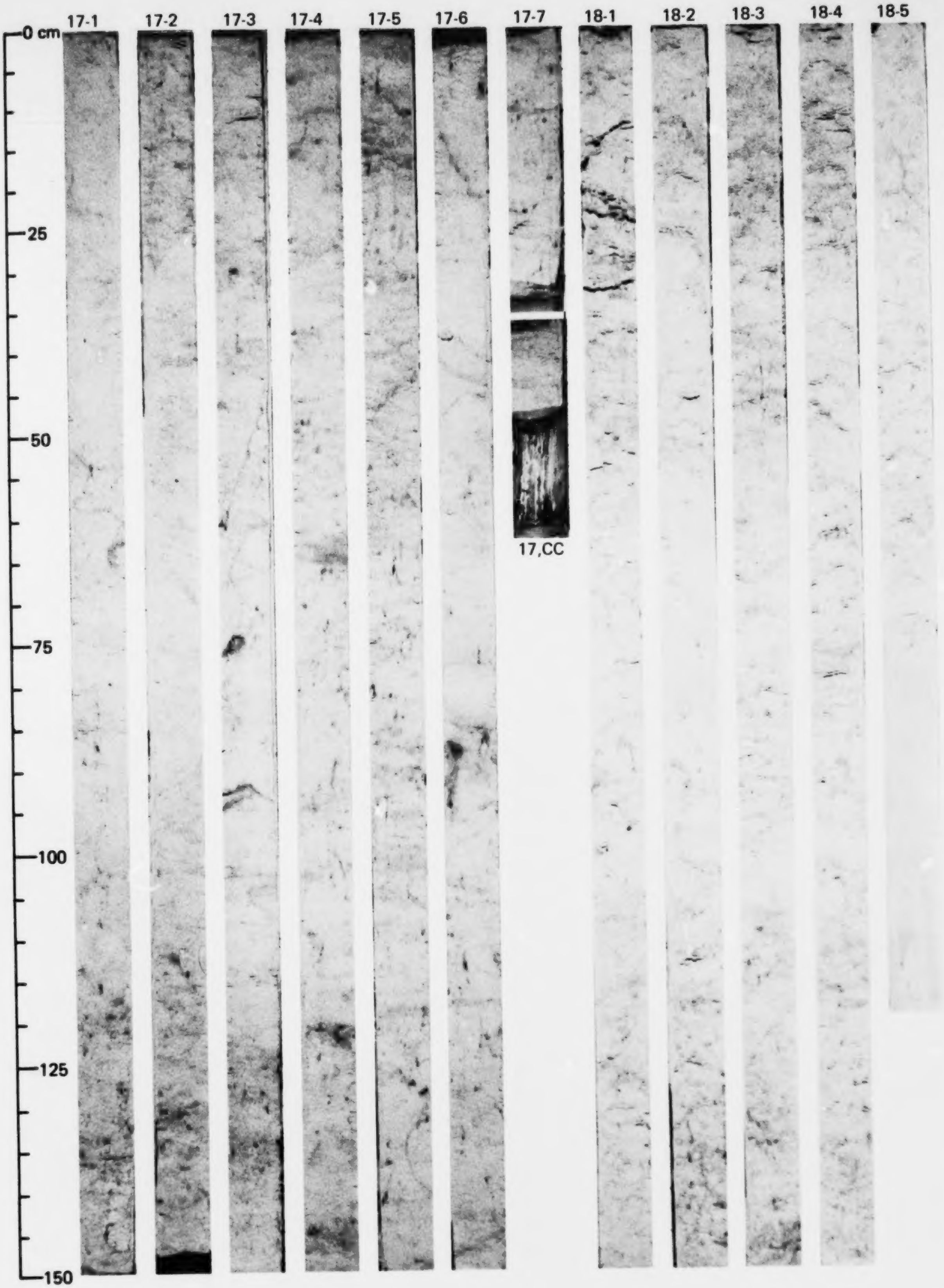

7-6
7-7
8-1
8-2
8-3
8-4
8-5
8-6
8-7
9-1
9-2
9-3
0 cm
25
50
75
100
125
150
7,CC
8,CC

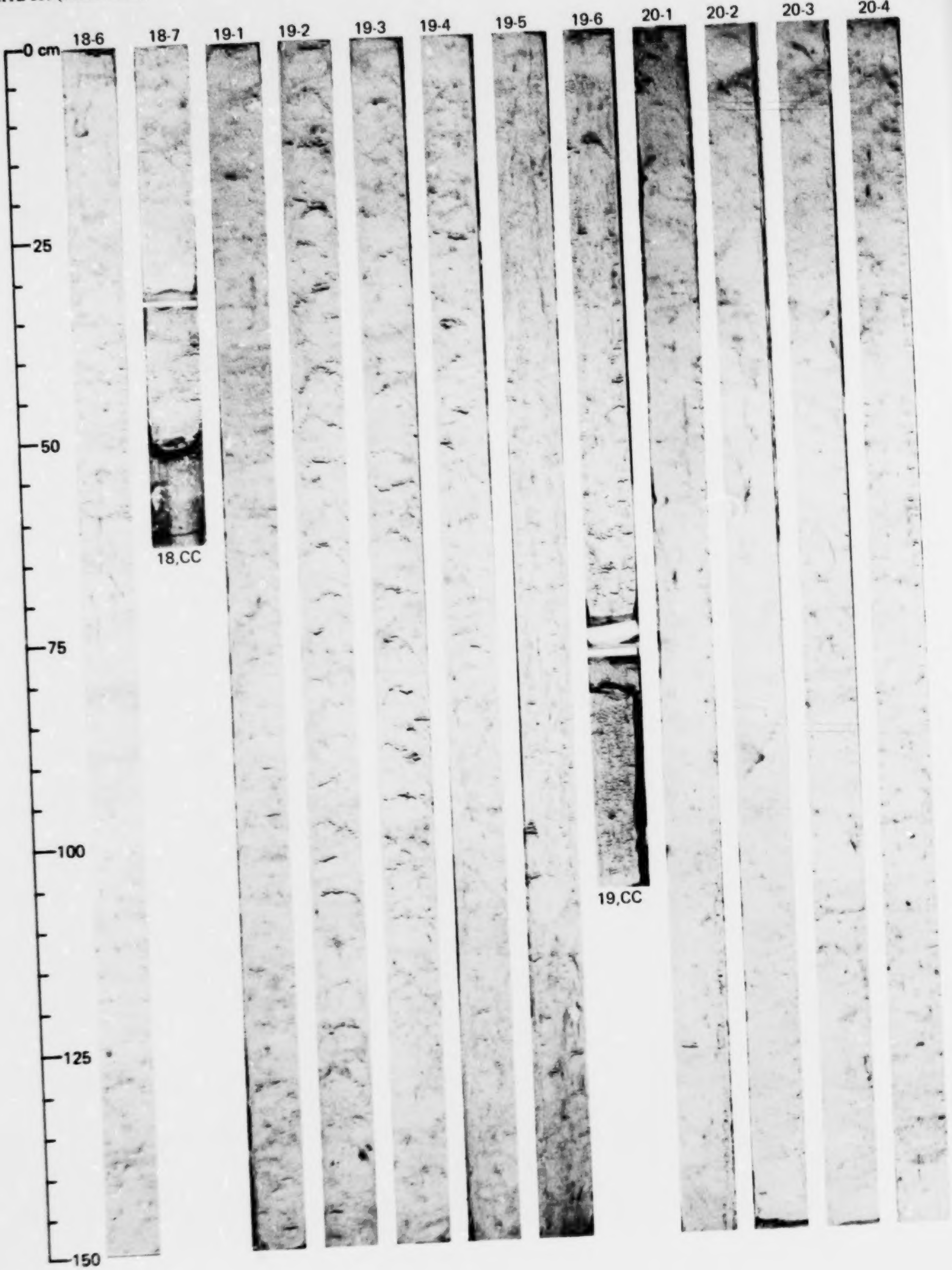

9-4
9-5
9-6
9-7
10-1
10-2
10-3
10-4
10-5
10-6
10-7
11-1
0 cm
25
50
75
100
125
150
9,CC
10,CC

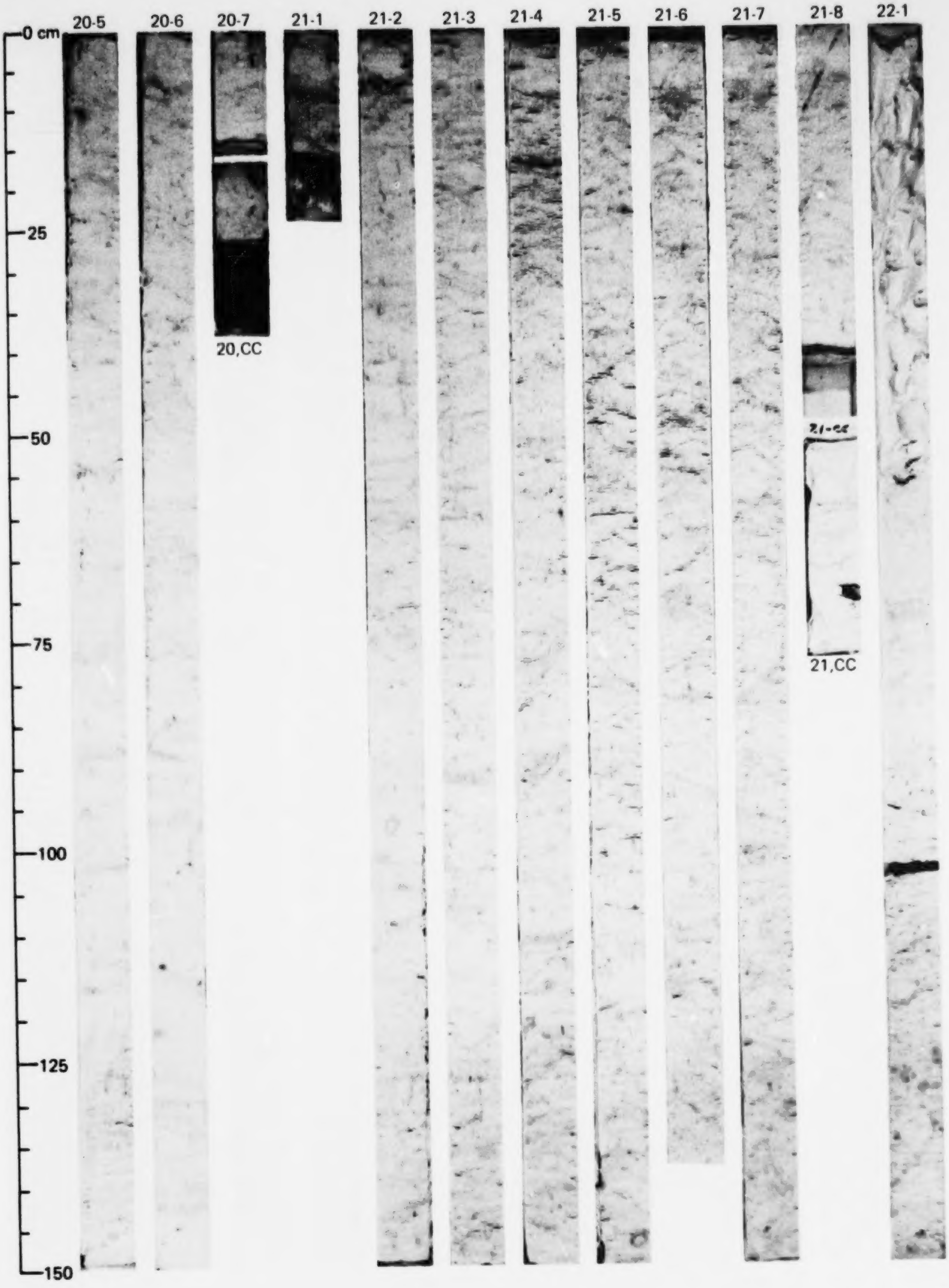

11-2
11-3
11-4
11-5
11-6
11-7
12-1
12-2
12-3
12-4
12-5
12-6
0 cm
25
50
75
100
125
150
11,CC

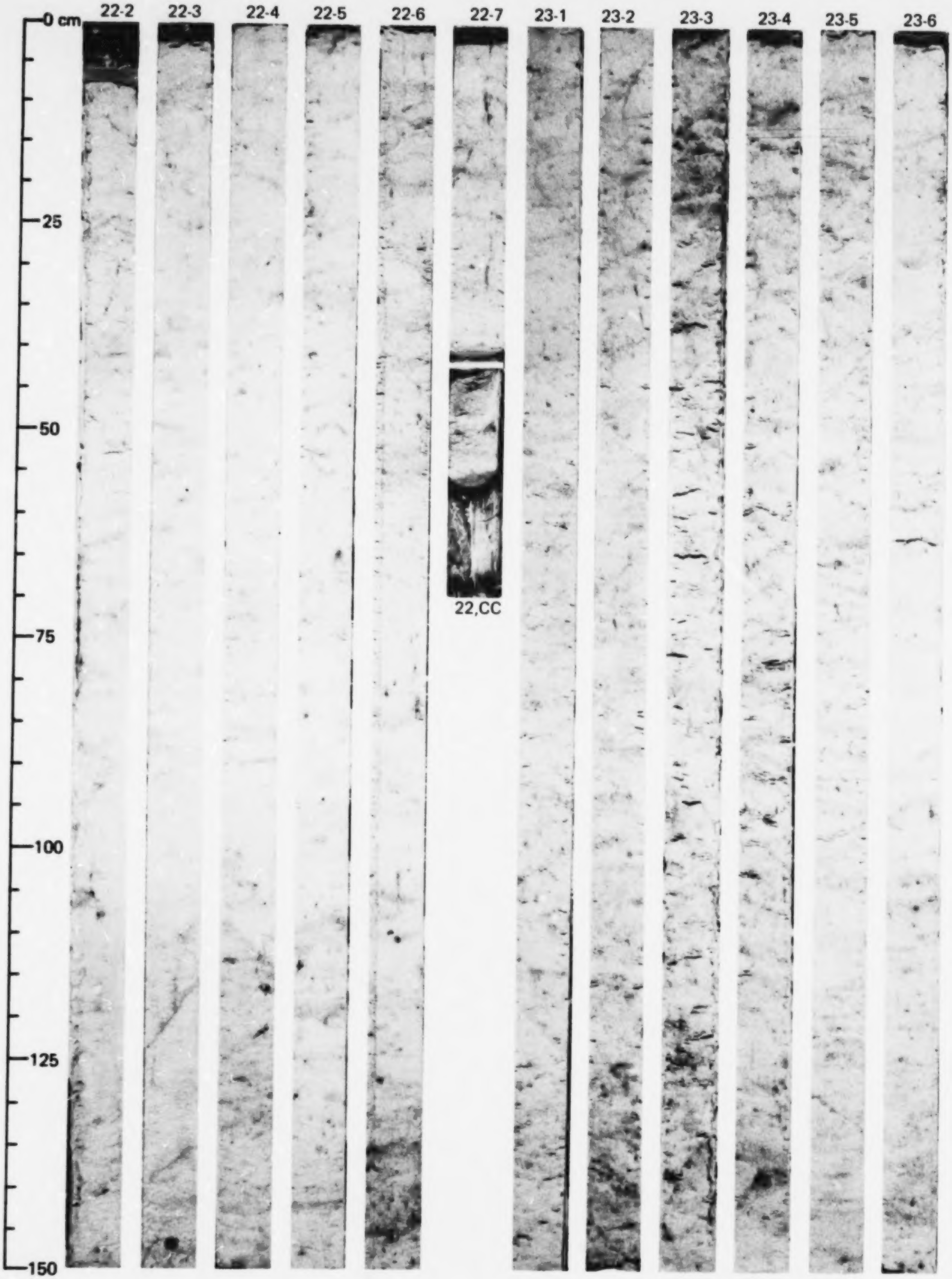

12-7
13-1
13-2
13-3
13-4
13-5
14-1
14-2
14-3
14-4
15-1
15-2
0 cm
25
50
75
100
125
150
12,CC
13,CC
14,CC

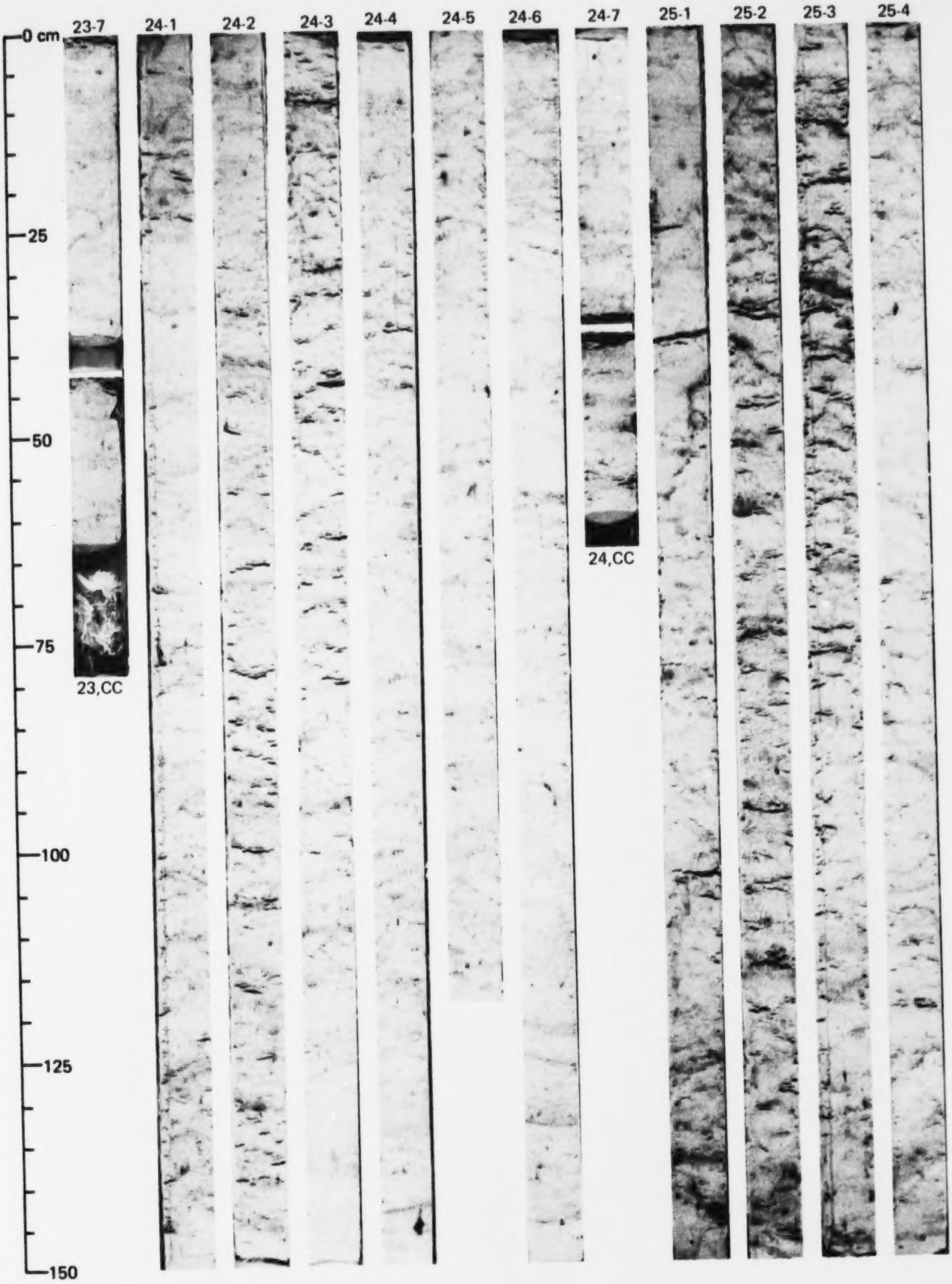

15-3
15-4
15-5
15-6
15,CC
16-1
16-2
16-3
16-4
16-5
16-6
16-7
16,CC
0 cm
25
50
75
100
125
150


17-1
17-2
17-3
17-4
17-5
17-6
17-7
18-1
18-2
18-3
18-4
18-5
0 cm
25
50
75
100
125
150
17,CC

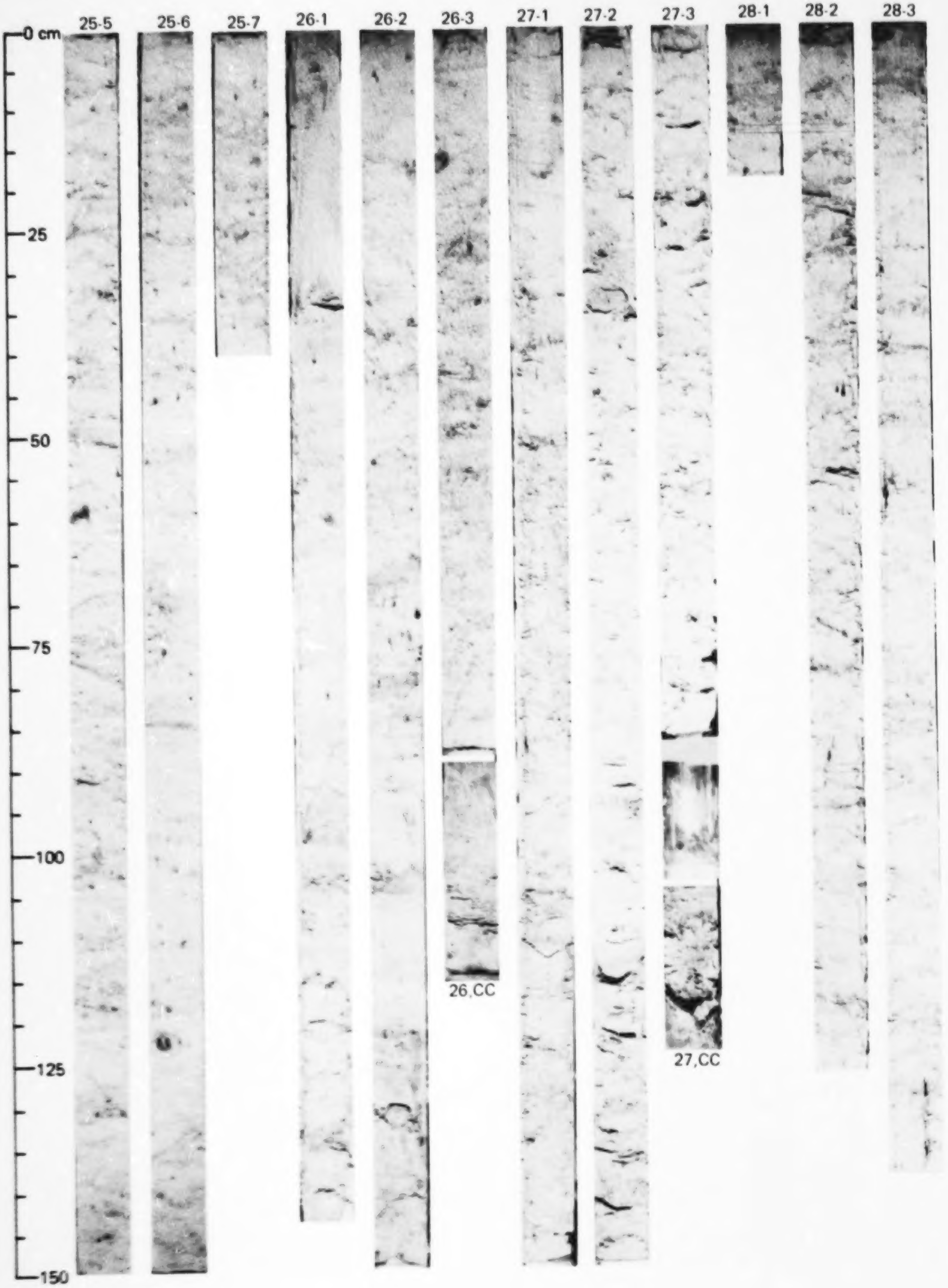

18-6
18-7
19-1
19-2
19-3
19-4
19-5
19-6
20-1
20-2
20-3
20-4
0 cm
25
50
75
100
125
150
18,CC
19,CC

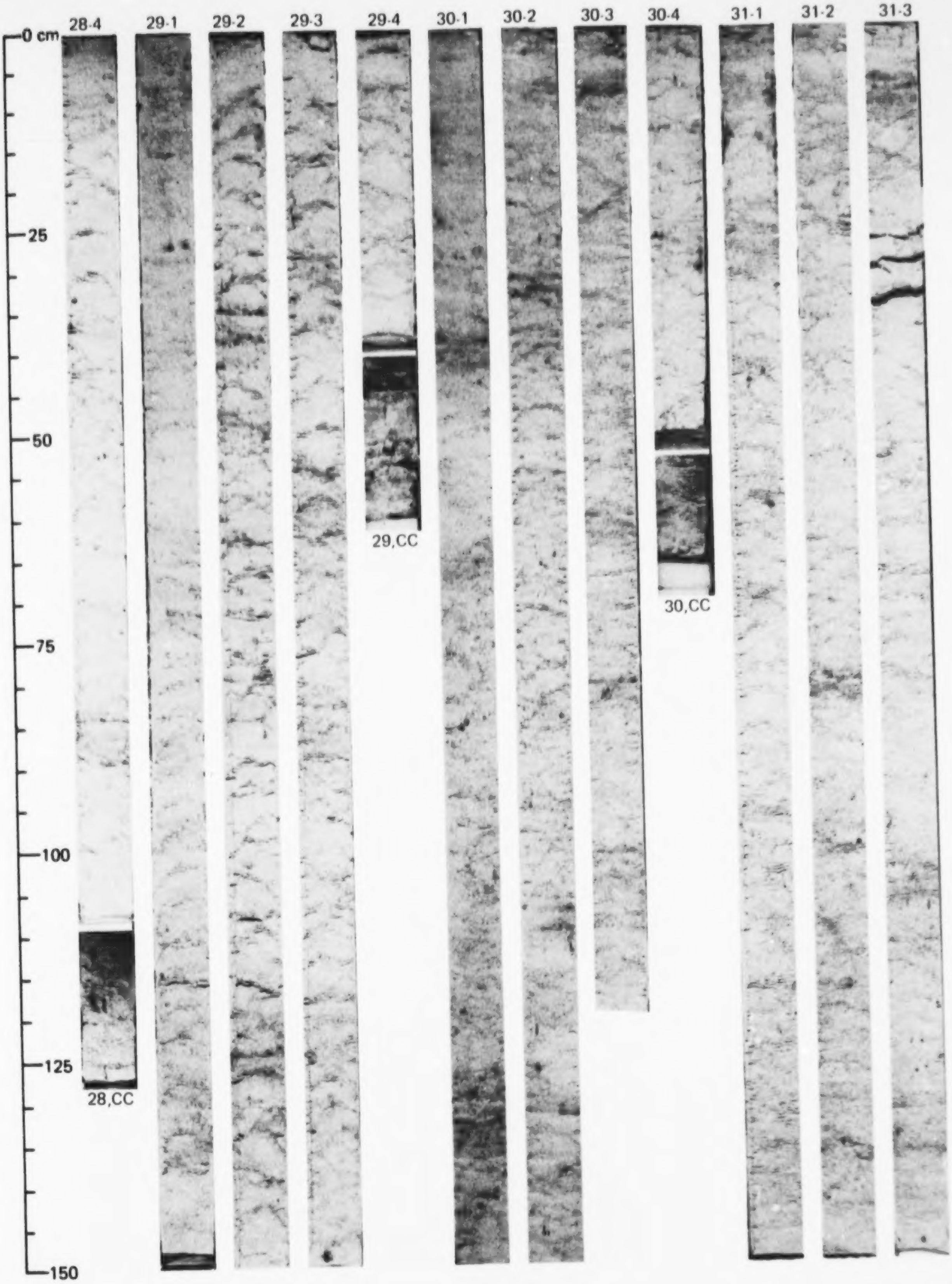

0 cm
25
50
75
100
125
150
20-5
20-6
20-7
21-1
21-2
21-3
21-4
21-5
21-6
21-7
21-8
22-1
20,CC
21-CC
21,CC

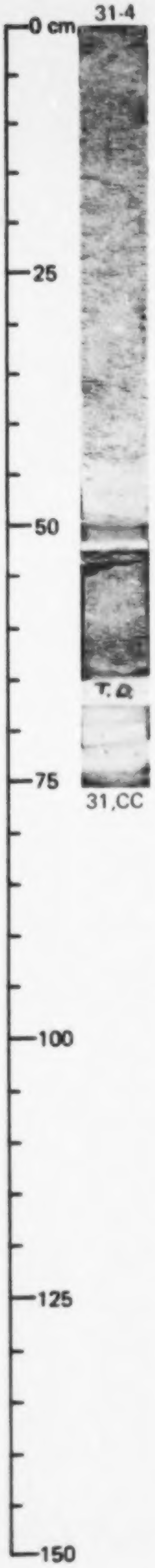

0 cm
25
50
75
100
125
150
22-2
22-3
22-4
22-5
22-6
22-7
22,CC
23-1
23-2
23-3
23-4
23-5
23-6

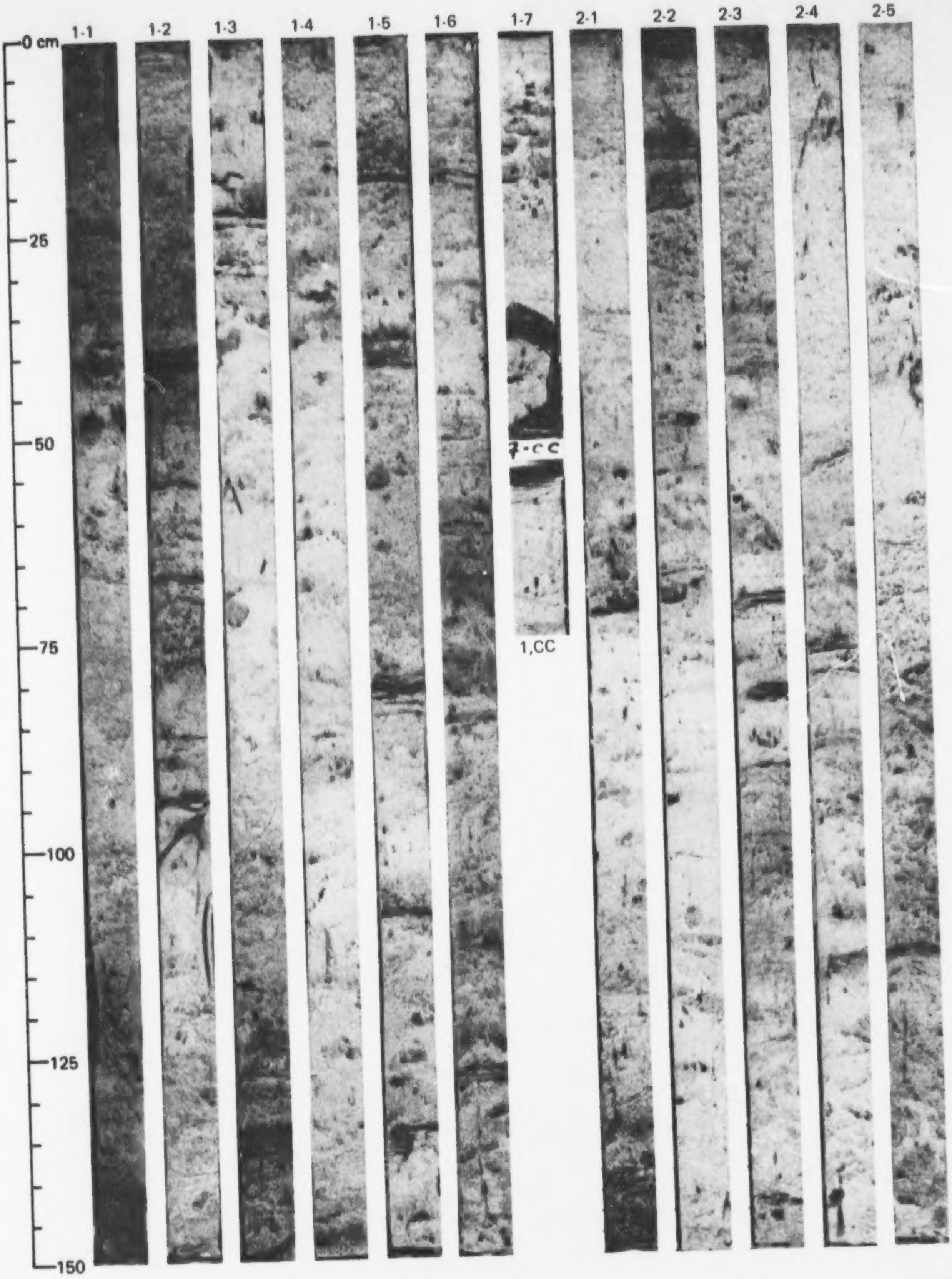


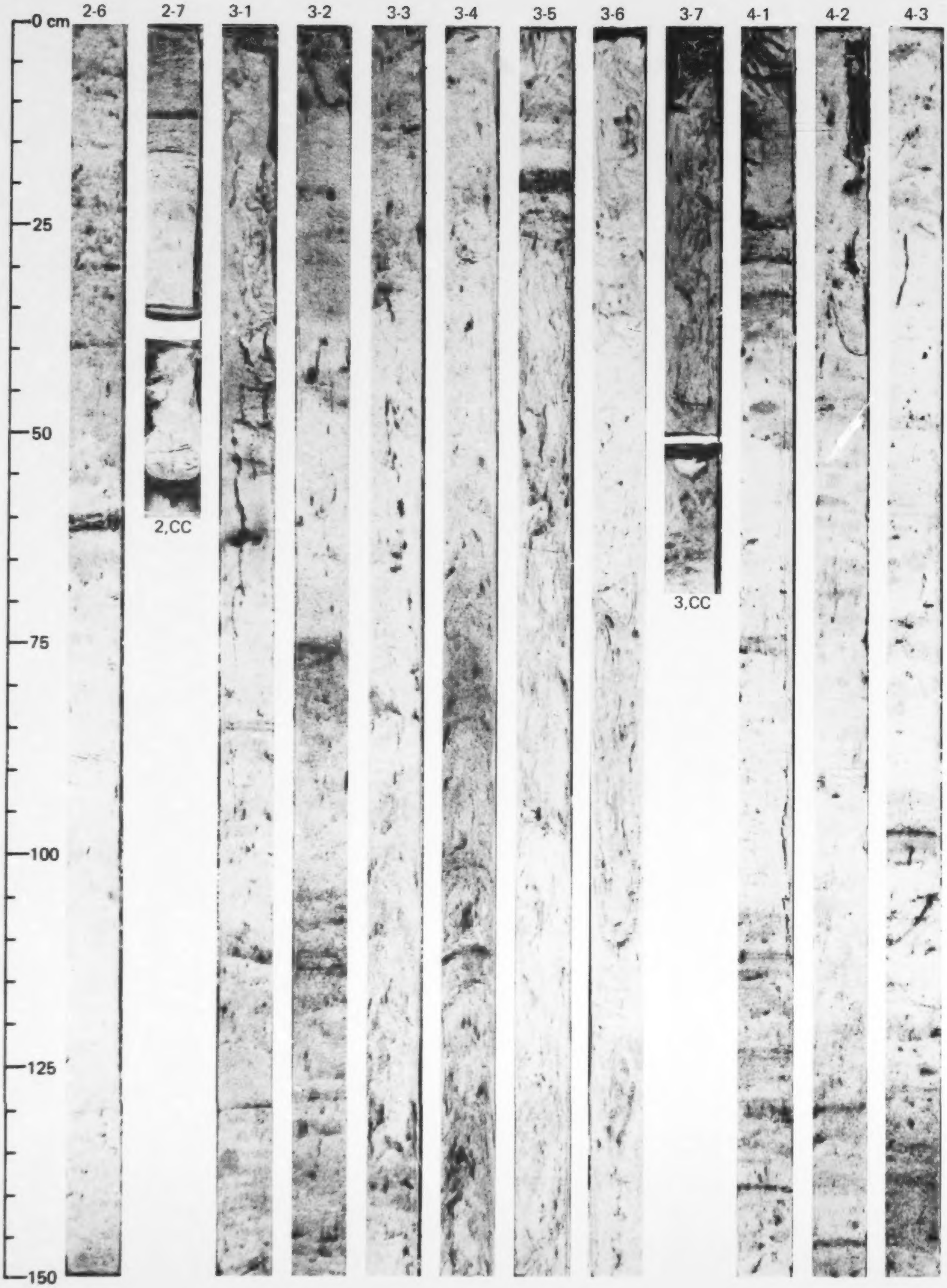
0 cm
25
50
75
100
125
150
23-7
23,CC
24-1
24-2
24-3
24-4
24-5
24-6
24-7
24,CC
25-1
25-2
25-3
25-4

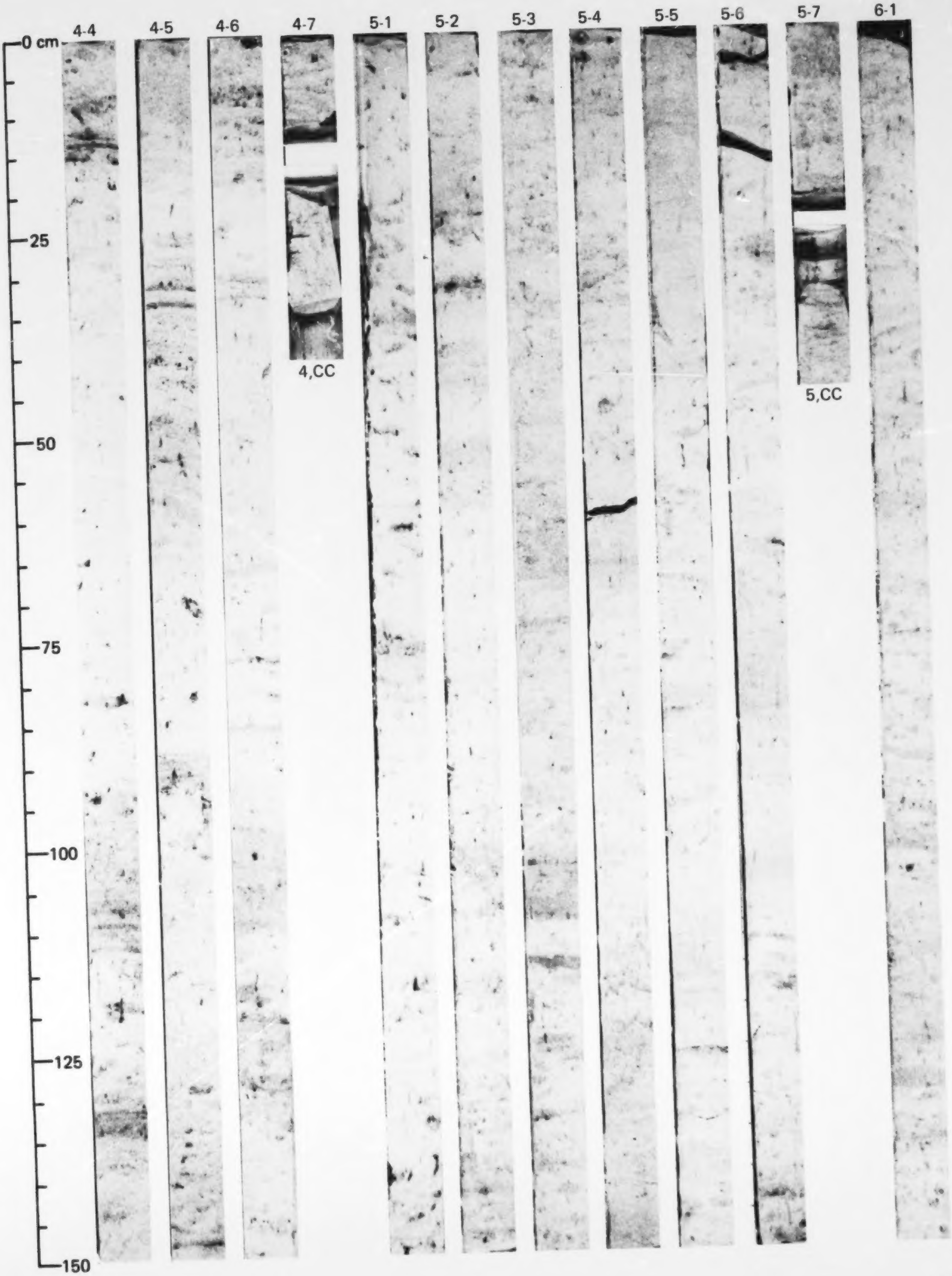

25-5
25-6
25-7
26-1
26-2
26-3
27-1
27-2
27-3
28-1
28-2
28-3
0 cm
25
50
75
100
125
150
26,CC
27,CC

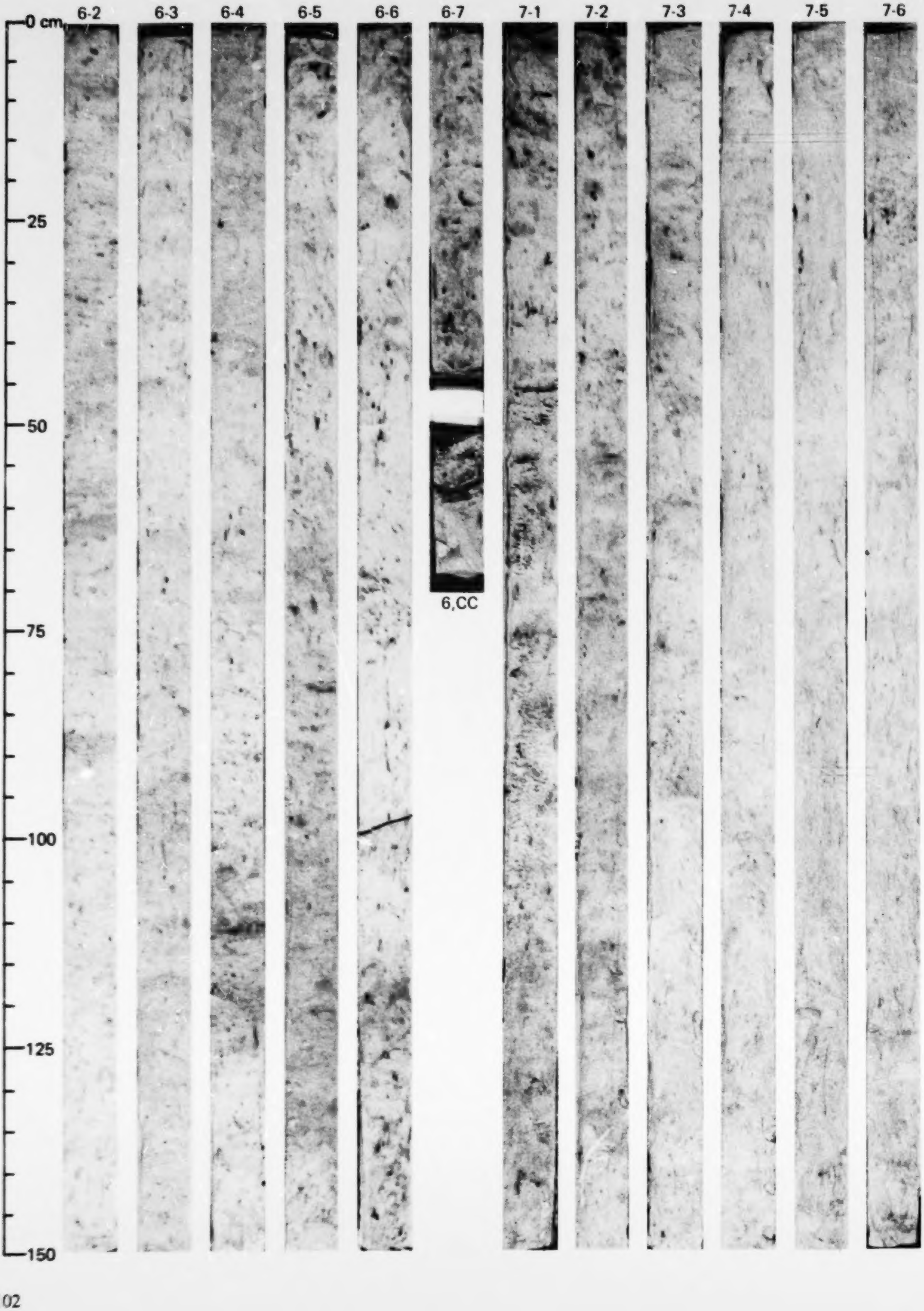

28-4
29-1
29-2
29-3
29-4
30-1
30-2
30-3
30-4
31-1
31-2
31-3
0 cm
25
50
75
100
125
150
28,CC
29,CC
30,CC

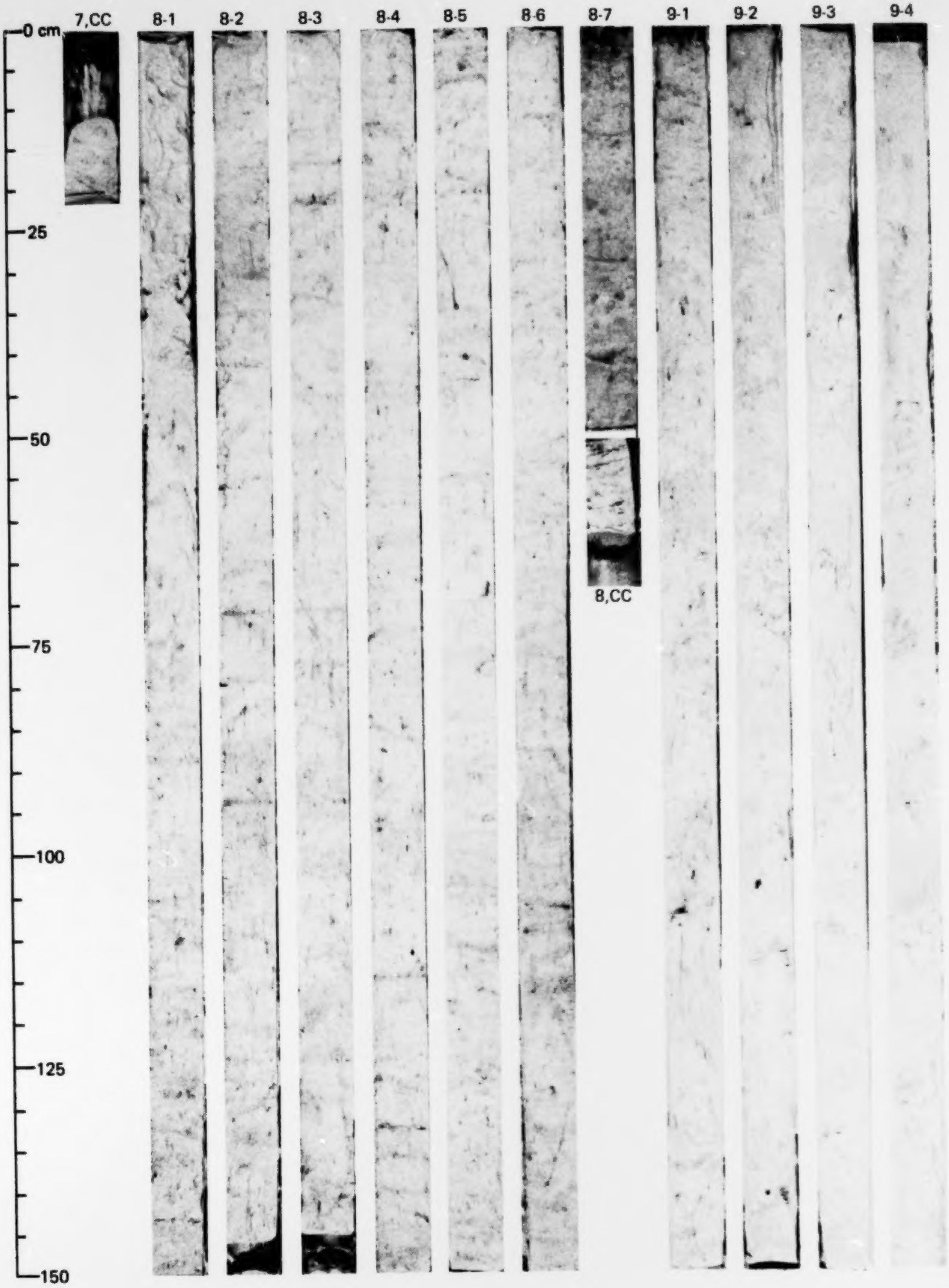

31-4
0 cm
25
50
T.D.
75
31,CC
100
125
150


1-1
1-2
1-3
1-4
1-5
1-6
1-7
2-1
2-2
2-3
2-4
2-5
0 cm
25
50
75
100
125
150
7-CC
1,CC


0 cm
25
50
75
100
125
150
2-6
2-7
3-1
3-2
3-3
3-4
3-5
3-6
3-7
4-1
4-2
4-3
2,CC
3,CC


0 cm
25
50
75
100
125
150
4-4
4-5
4-6
4-7
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5,CC
6-1


6-2
6-3
6-4
6-5
6-6
6-7
7-1
7-2
7-3
7-4
7-5
7-6
0 cm
25
50
75
100
125
150
6,CC


0 cm
25
50
75
100
125
150
7,CC
8-1
8-2
8-3
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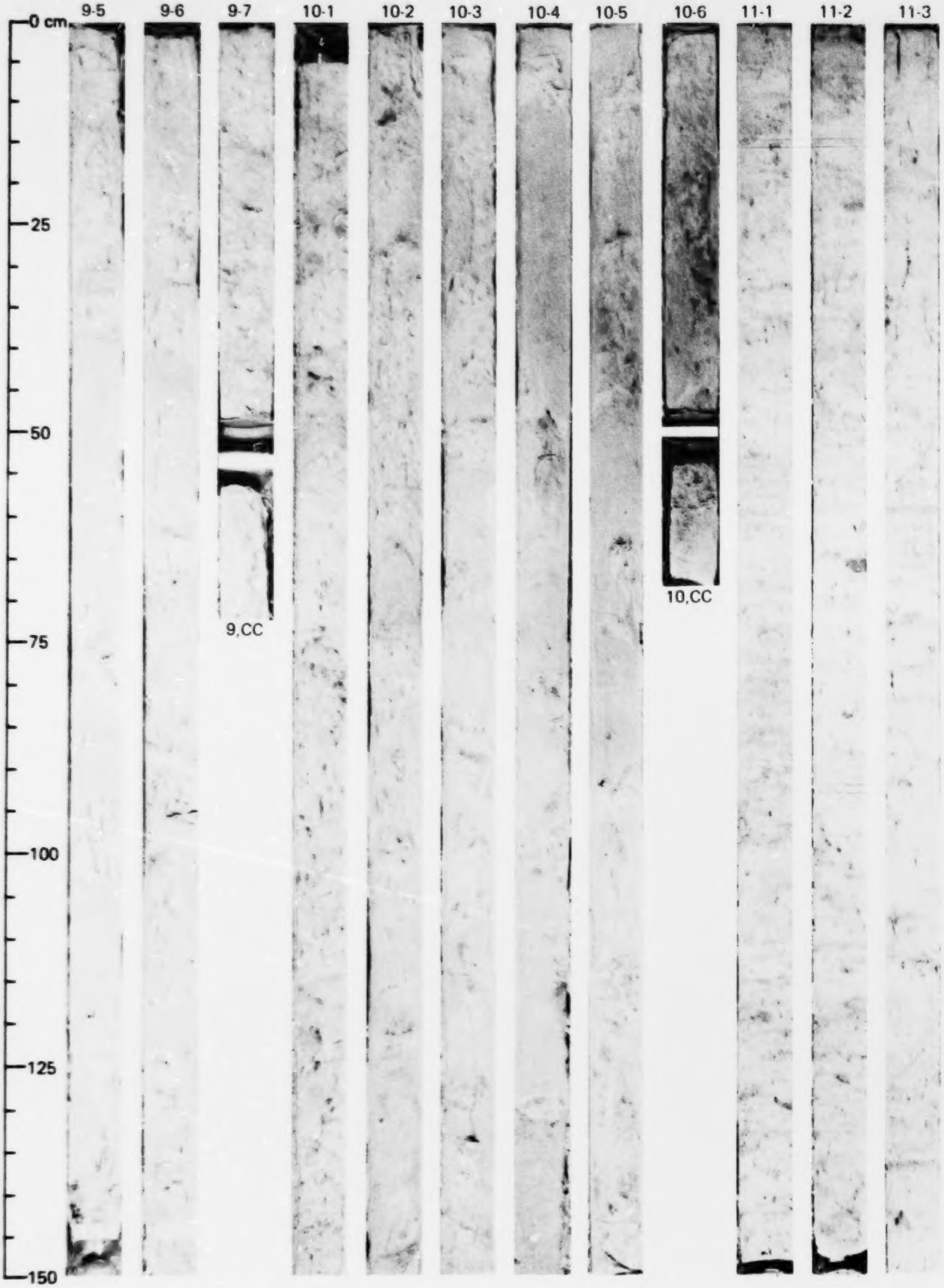
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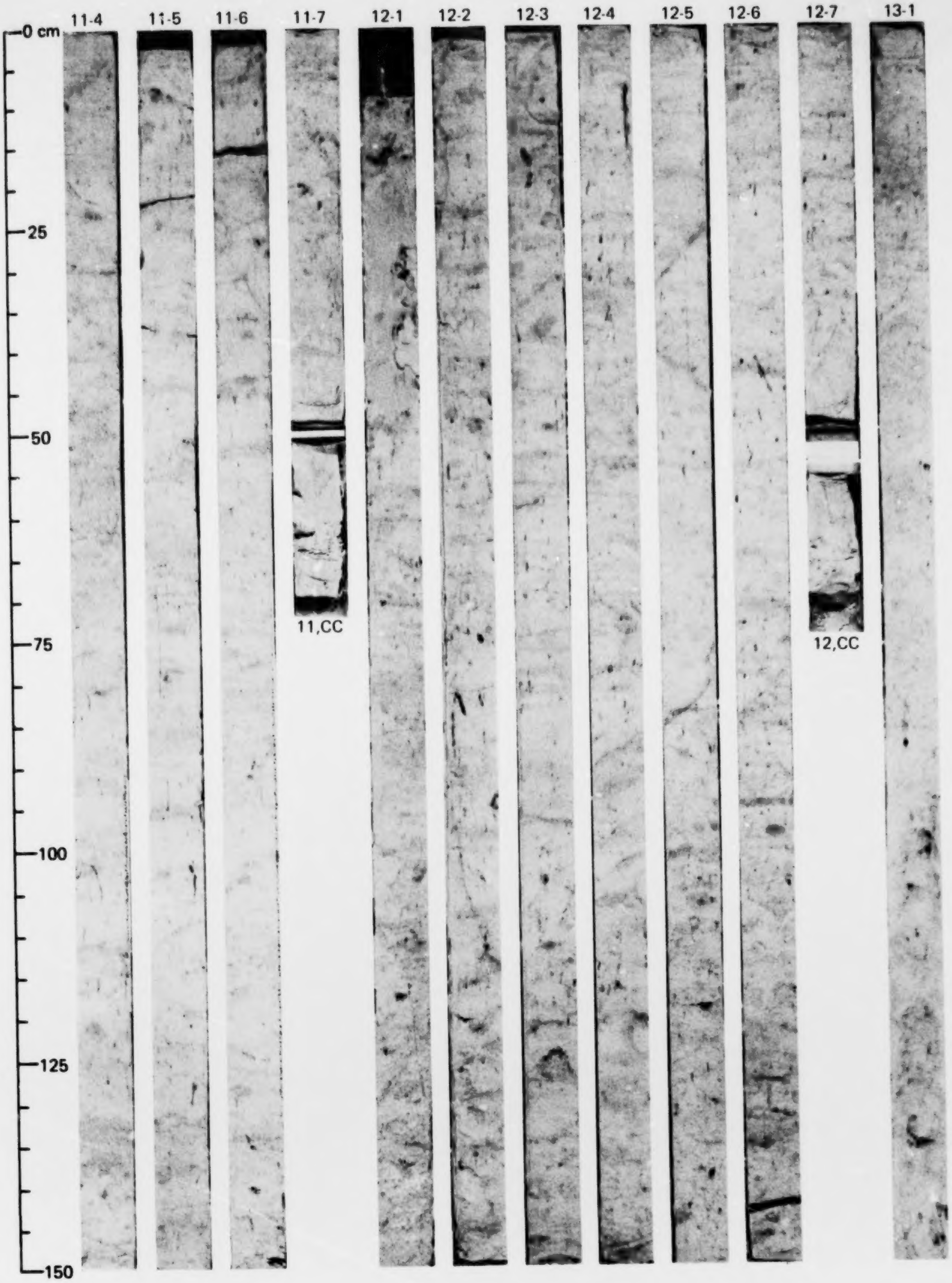
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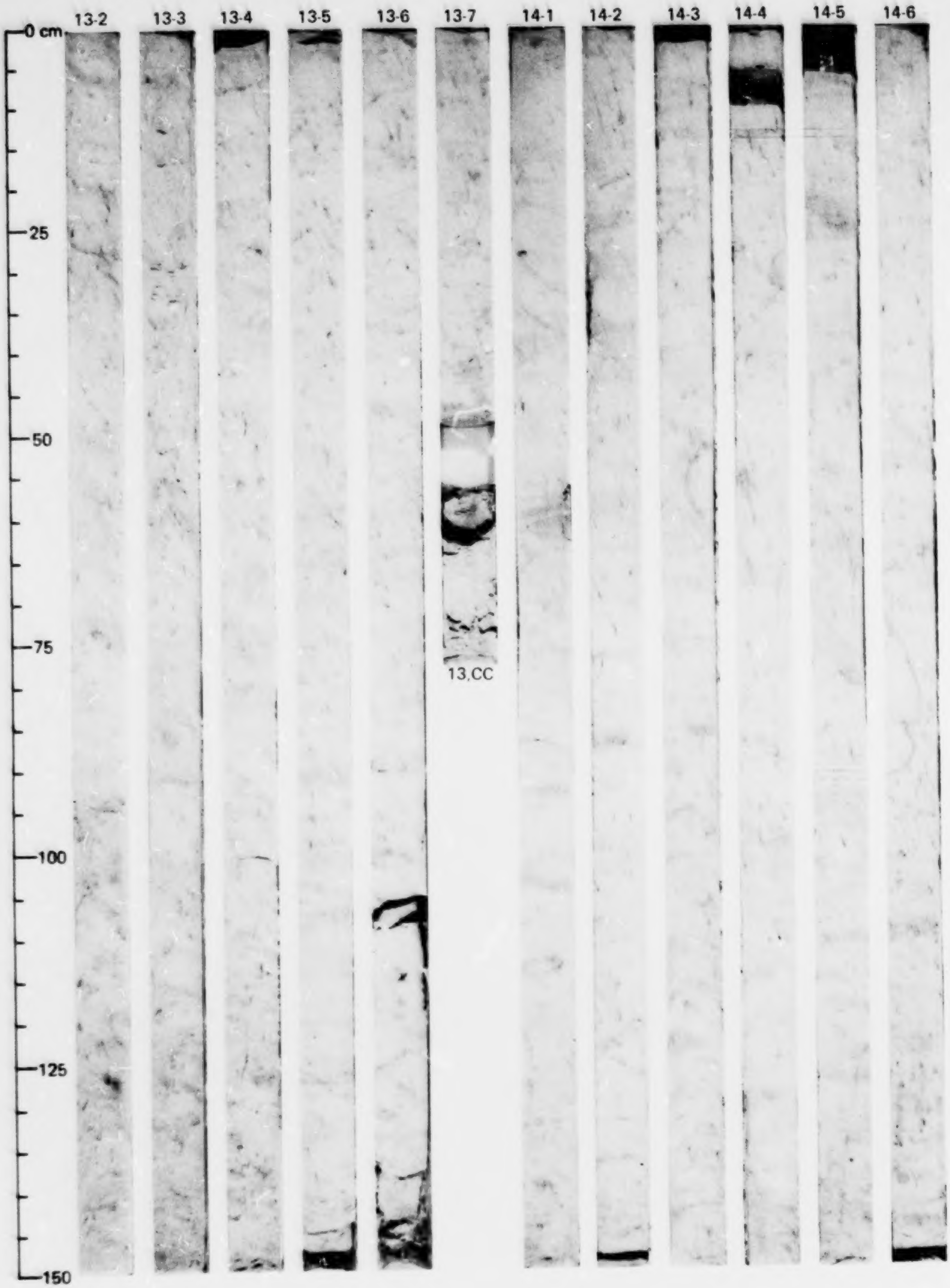
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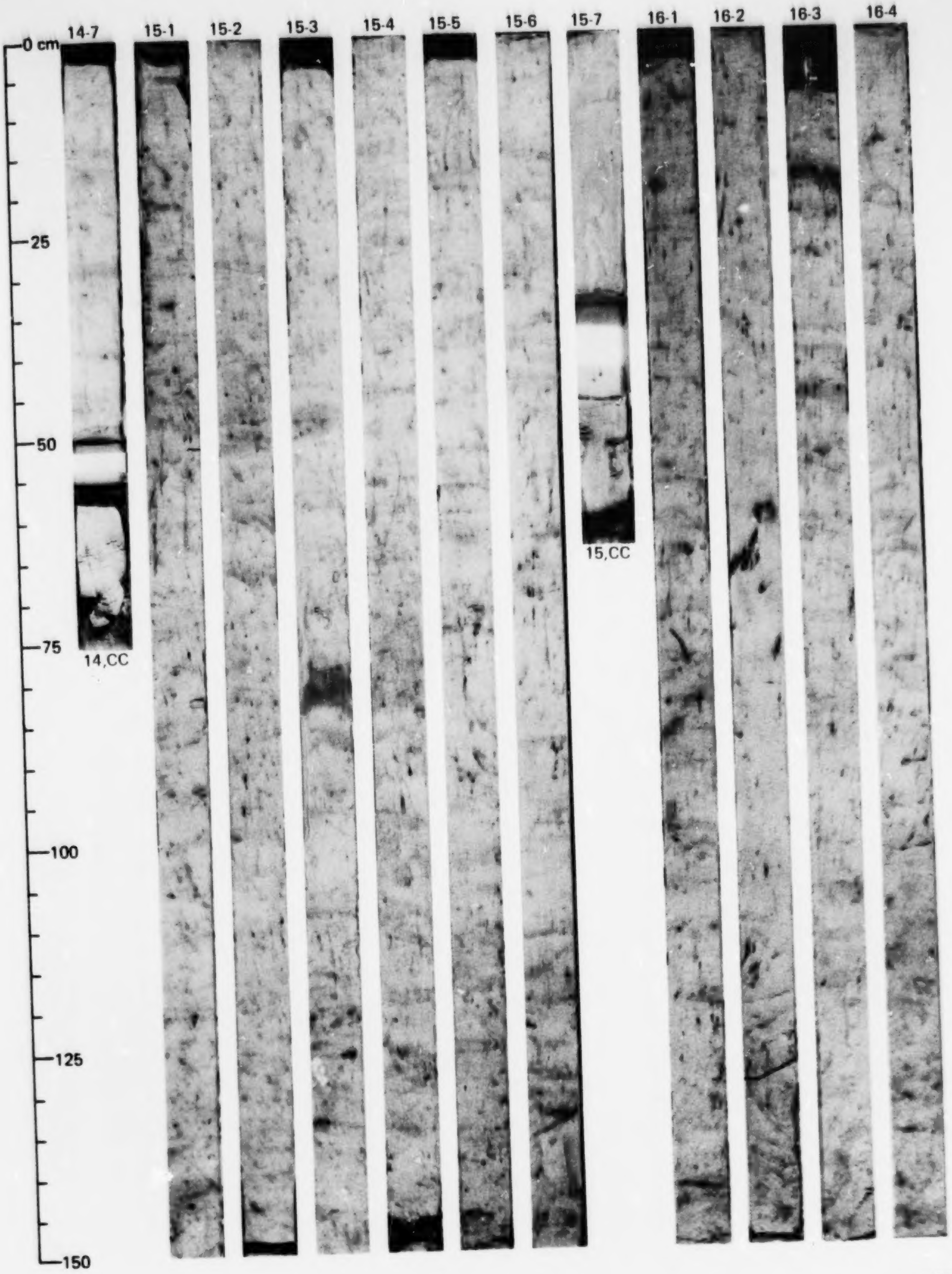
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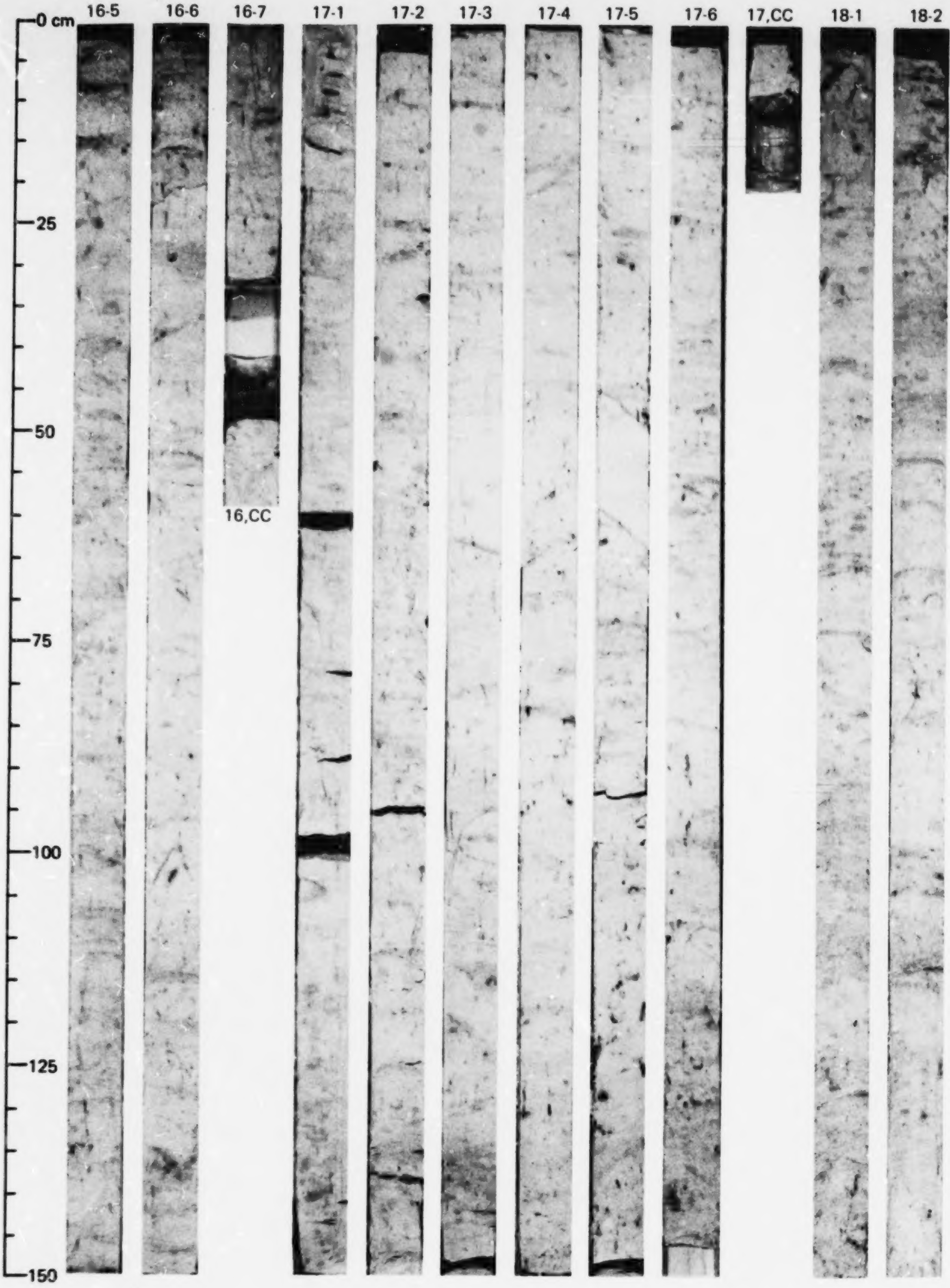
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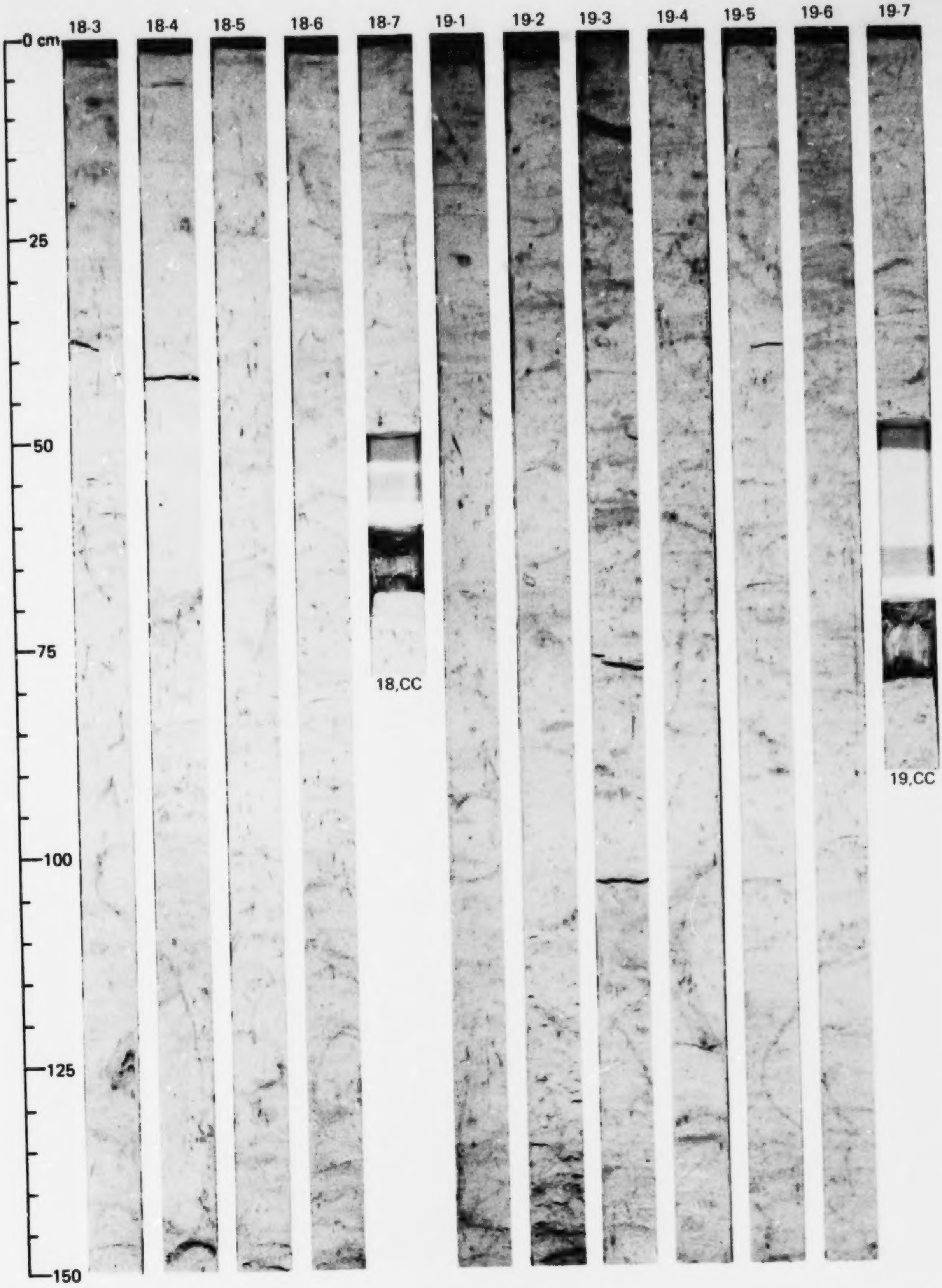
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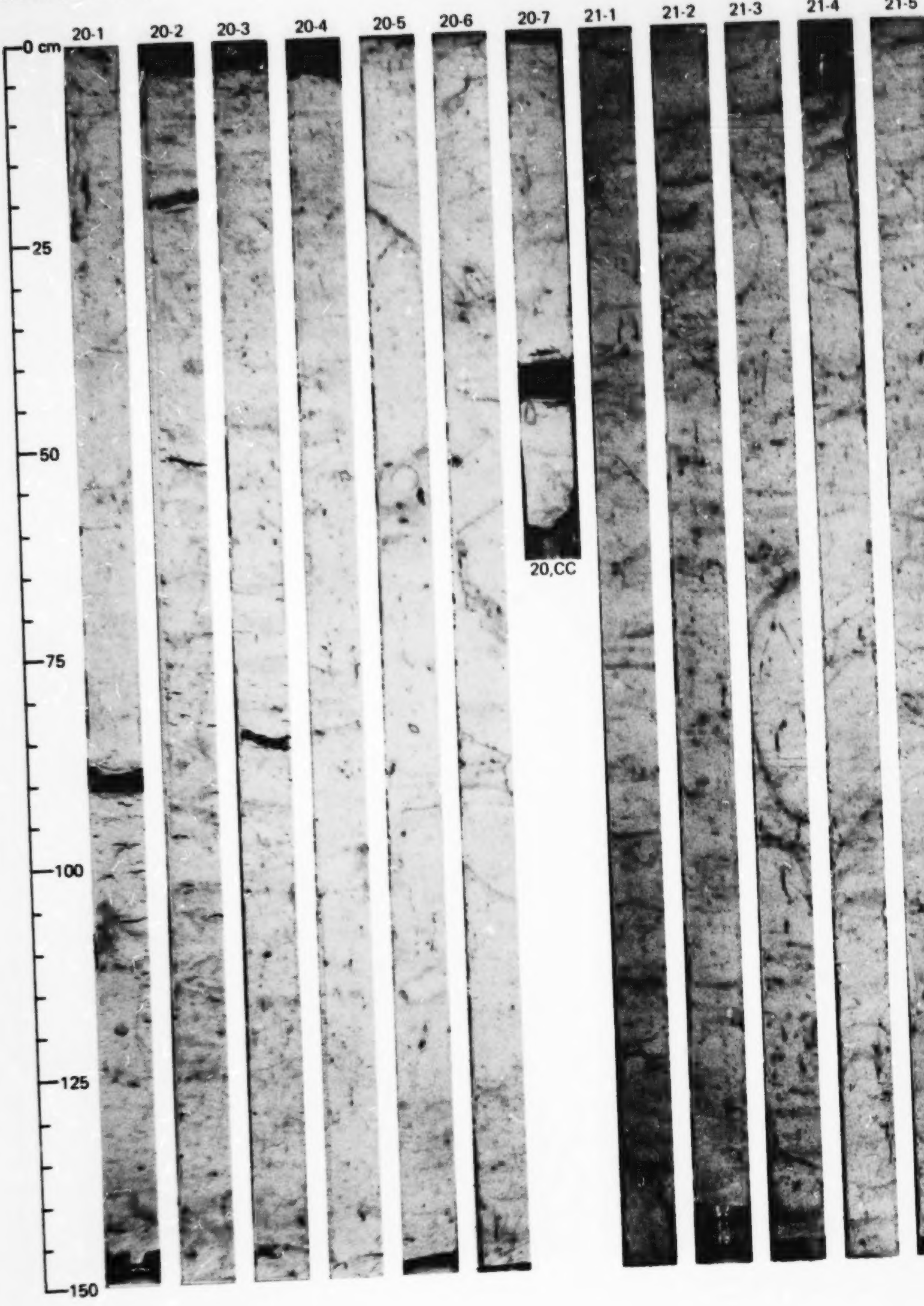

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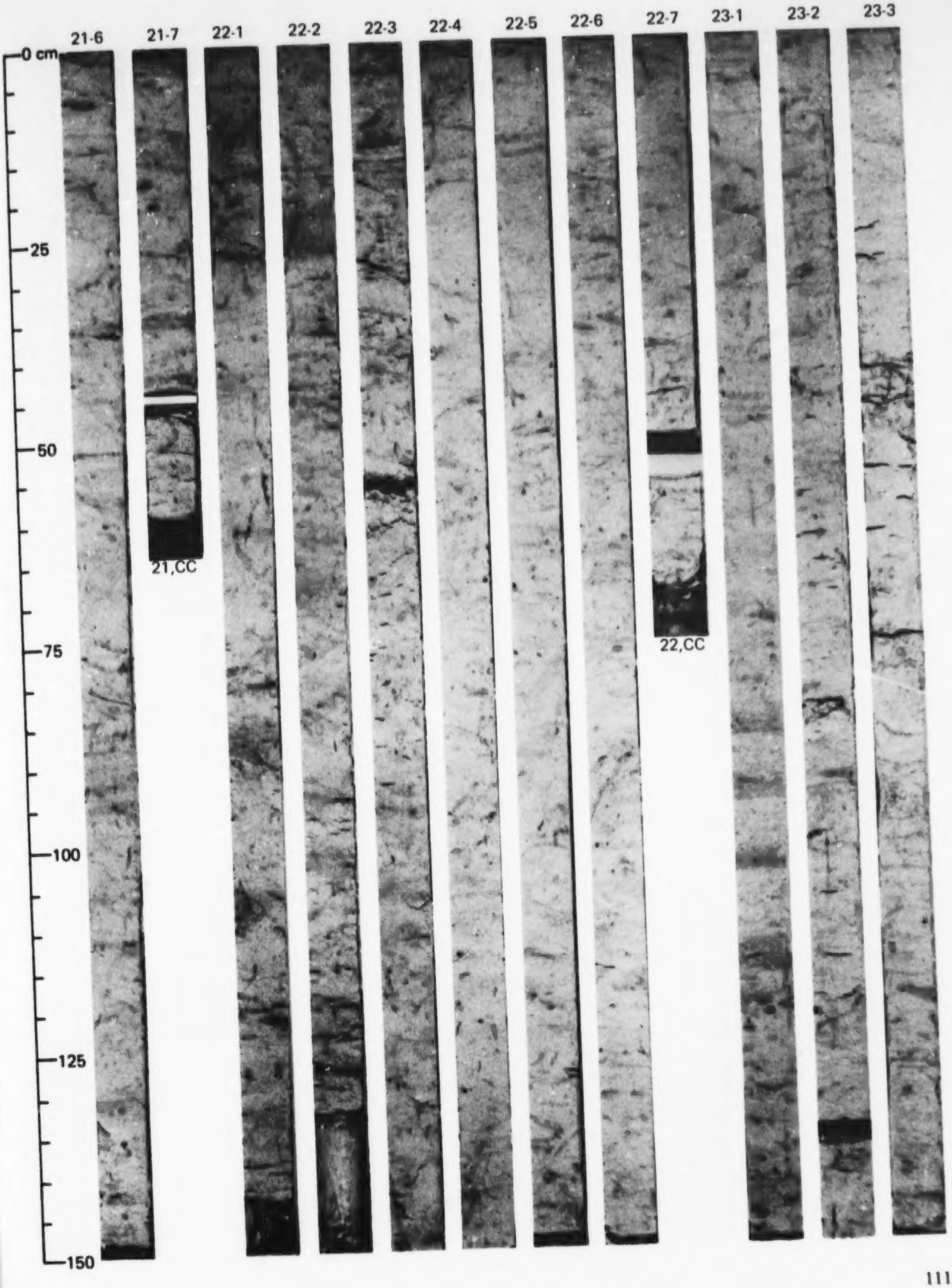
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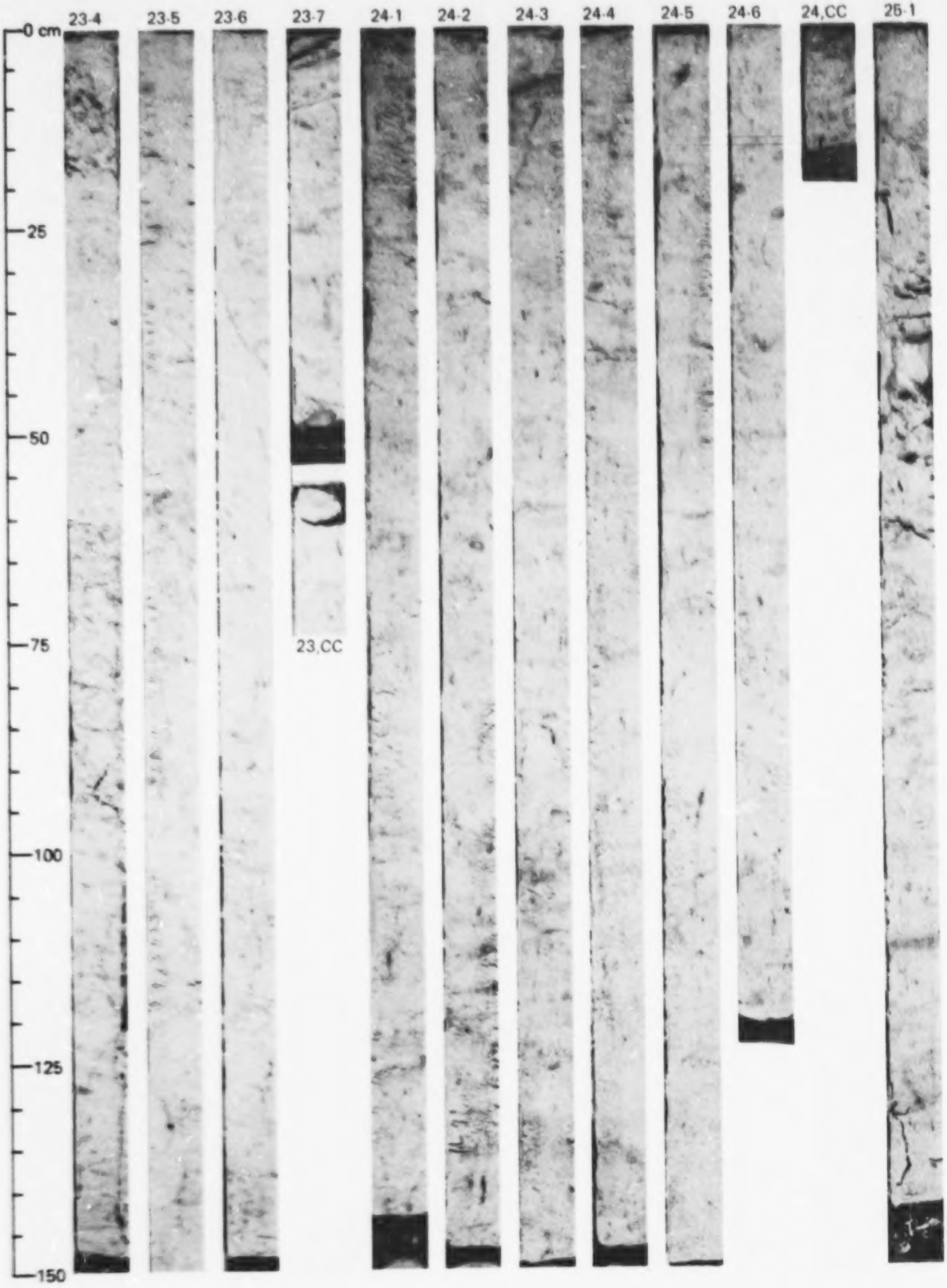
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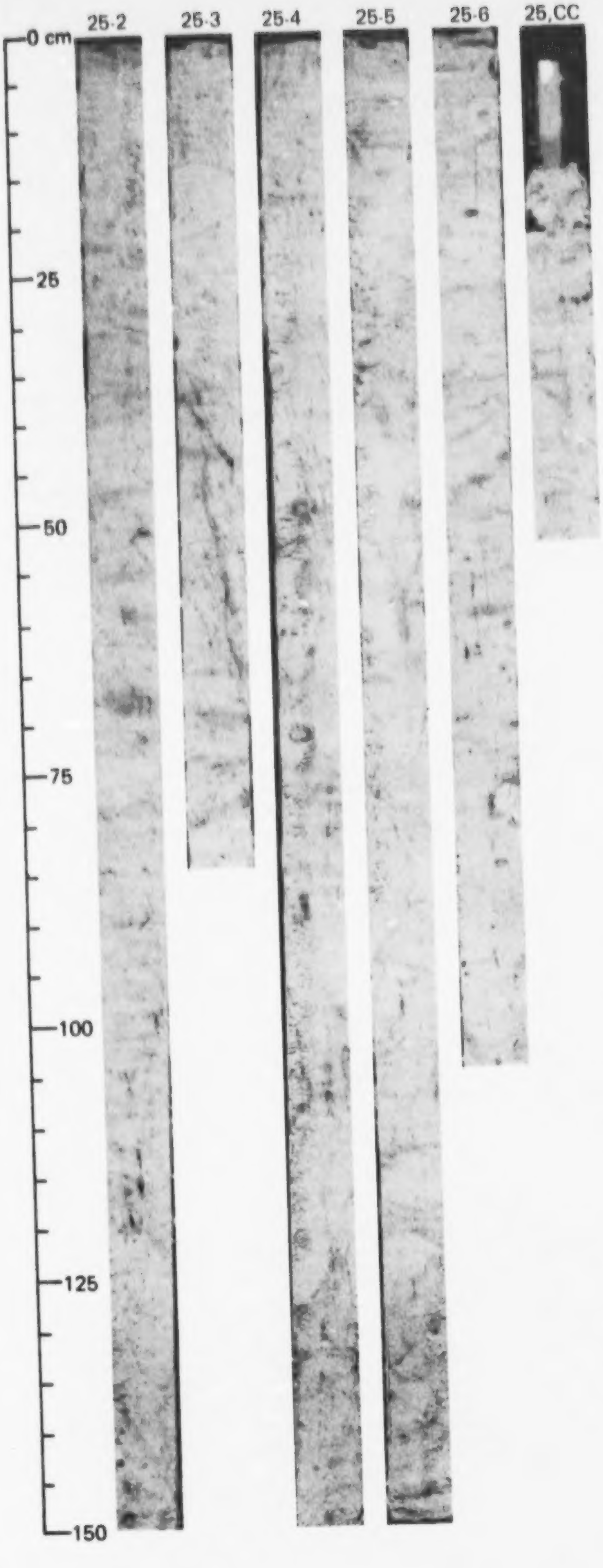
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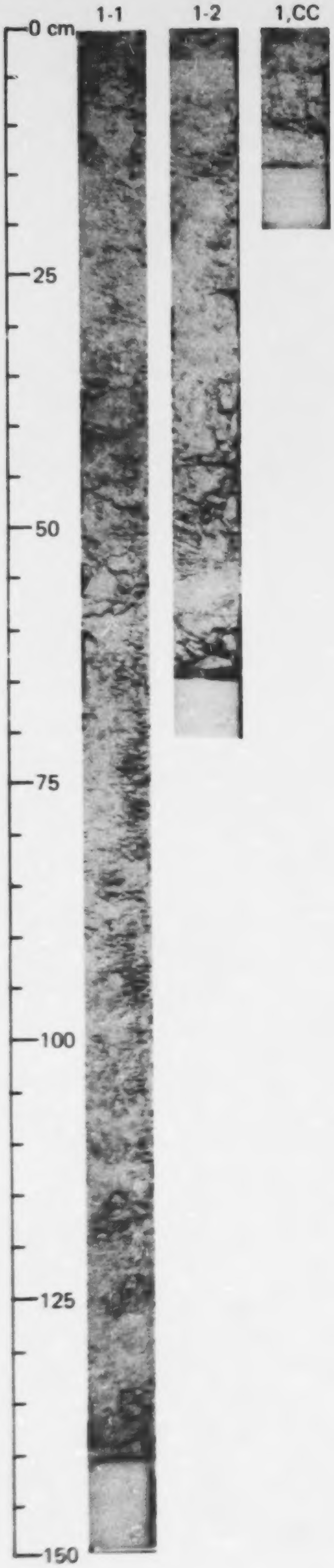
SITE 586 (HOLE 586C)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3. SITE 587: LANSDOWNE BANK, SOUTHWEST PACIFIC[1]

Shipboard Scientific Party[2]

HOLE 587

Date occupied: 3 December 1982

Date departed: 5 December 1982

Time on hole: 40 hr.

Position: 21°11.087'S; 161°19.99'E

Water depth (sea level; corrected m, echo-sounding): 1101

Water depth (rig floor; corrected m, echo-sounding): 1111

Bottom felt (m, drill pipe): 1115

Penetration (m): 147

Numbers of cores: 17

Total length of cored section (m): 147 (89.5 in Pliocene)

Total core recovered (m): 88.81 (80.95 in Pliocene)

Core recovery (%): 60.4 (90% in Pliocene)

Oldest sediment cored:
Depth sub-bottom (m): 147
Nature: Calcareous sandstone
Age: Probably late Miocene

Basement: Not reached

Principal results: Site 587 is located on the southern slope of Lansdowne Bank in the southwest Pacific at 21° S, 161° E. At this site the hydraulic piston corer penetrated 147 m into the upper Miocene, with good recovery only in the Pliocene. The section consists of one major lithofacies, a foraminifer-bearing nannofossil ooze to foraminifer–nannofossil ooze, interbedded with minor lithofacies of coarse-grained sediment consisting of skeletal silty sands to skeletal sandy gravels. The coarse sediment facies consists of redeposited sediments of shallow-water origin, especially corals, calcareous algae, bryozoa, and shallow-water foraminifers from the photic zone. These sediments were probably deposited during low stands of sea level.

Three successful *in situ* temperature measurements provide a linear temperature profile with depth, details of which are provided in Morin (this volume).

BACKGROUND AND OBJECTIVES: LANSDOWNE BANK, SOUTHWEST PACIFIC

Site 587 is located on the southern slope of the Lansdowne Bank (Fig. 1) which represents the most northern part of Lord Howe Rise. Lansdowne Bank lies between Lord Howe Basin to the west and New Caledonia Basin to the east. The bank rises to a present-day water depth of only 100 m and the crest lies within the photic zone (Launay et al., 1977; Ravenne et al., 1977).

Site 587 was selected in order to obtain an uncomplicated, high-resolution calcium carbonate sedimentary record of Neogene and late Paleogene age in an area between the warm subtropics and the equator. This location was chosen because it lies close to the edge of the true tropics at 21°S, is in shallow depths (1100 m) to guarantee a calcareous pelagic sedimentary section and should provide an apparently uncomplicated stratigraphic sequence with no major terrigenous sedimentary input. However, during the selection process for Site 587, it was discovered that few shallow-water features exist at about 20°S in the southwest Pacific that might provide the kind of sequence of interest. The flanks of Lansdowne Bank exhibit a source of high-amplitude reflections in the upper part (0.4 s) of the section (Fig. 2) which, it was thought, might represent calcareous sediments transported from the shallow waters at the crest of the bank. Because of this, the site was considered to

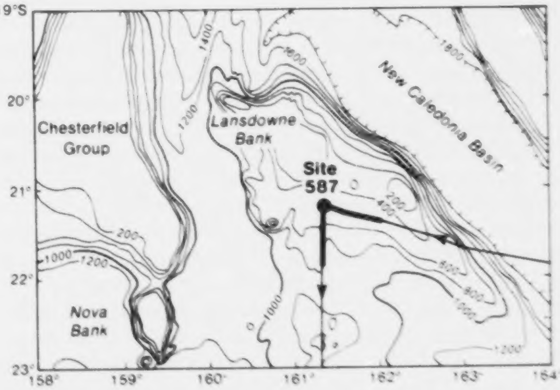

Figure 1. Regional bathymetry (fathoms) around Site 587, after Mammerickx et al. (1974) *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), School of Earth Sciences, Flinders University of South Australia, Bedford Park, South Australia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; Charles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, P.O. Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, Stony Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National d'Histoire Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Sciences Division, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 96720; James V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Sciences, Open University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United Kingdom; William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, Littleton, CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgang-Goethe Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic of Germany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Oceanography, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, College Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. Geological Survey, Denver Federal Center, Denver, CO 80225); Campbell S. Nelson, Department of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Christian Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 13288 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu University, Varanasi 221 005, India; Rüdiger Stein, Geologisch-Paläontologisches Institut, Universität Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petroleum and Organic Geochemistry (ICH-5), Kernforschungslage Jülich GmbH, P.O. Box 1913, 5170 Jülich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, Faculty of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

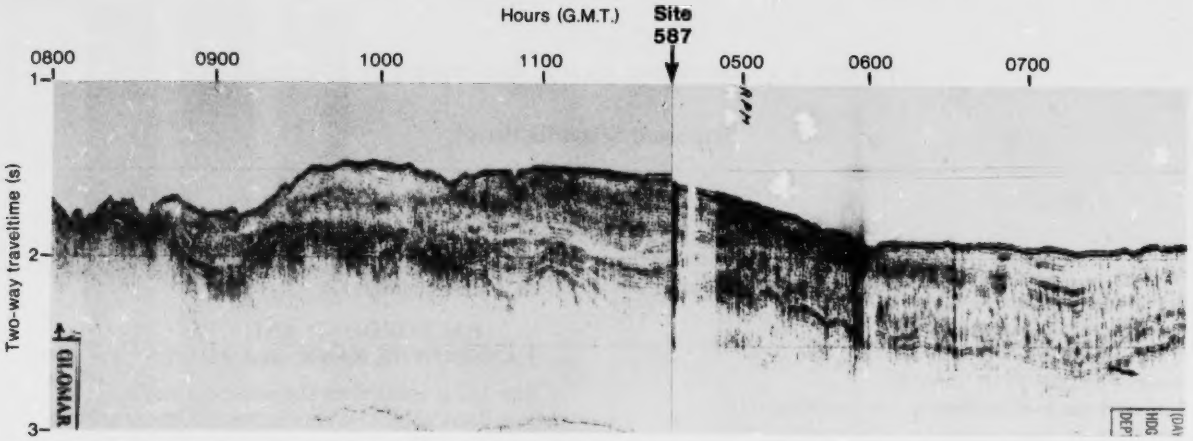

Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 587; bandpass filter 40–160 Hz.

be suboptimal, but other areas at these latitudes seemed to be no less complicated.

The specific objectives at Site 587 were to obtain a continuous section through calcareous oozes of late Oligocene and Neogene age near the edge of the tropics. A stratigraphic linkage section was required between two previously drilled sites of high biostratigraphic quality, Site 289 (and 586) on the equator and Site 208 (and 588) at 26°S in warm subtropics. There was particular interest in establishing a biostratigraphic sequence at about 20°S to assist with stratigraphic correlations between the equator and the warm subtropics and to monitor paleoceanographic oscillations of the tropical and warm subtropical surface water masses over the region. Approaches to be employed included stable isotope analysis ($\delta^{18}O$ and $\delta^{13}C$), qualitative and quantitative biostratigraphy, sedimentology, and magnetostratigraphy.

To meet these objectives the plan was to recover two hydraulic piston core (HPC) sections and a rotary-drilled section below the point at which the HPC became unusable.

OPERATIONS

Noumea to Site 587

The last mooring line was cast off from the Passenger Terminal in Noumea, New Caledonia at 1620 hr. on 2 December 1982, and the *Glomar Challenger* cleared the barrier reef bordering New Caledonia's southwest coast at 2042 hr. after having tested thrusters. Aboard were the normal complement of 45 Global Marine, Inc., personnel plus 28 technical staff and scientists.

Routine geophysical data were collected under way to Site 587 (SW-8), using a 12-kHz echo sounder, a 3.5-kHz reflection profiler, a magnetometer, and a water gun seismic profiling system. The water gun system, incorporating a MICA T model water gun of Seismic Systems, Inc. (80 cu. in. air requirement per shot) was a relatively new addition to *Glomar Challenger's* suite of underway geophysical equipment, and was used in place of the standard 60 and 120 cu. in. air guns. Records obtained by the water gun appeared superior to those obtained using the air guns, with excellent penetration (in excess of 1 s two-way traveltime), a subdued bubble-pulse, and resolution of fine sub-bottom reflectors.

The few seismic profiles which were available for site selection at Site 587 indicated simple Neogene stratigraphy and sub-bottom structure over a relatively broad area around the proposed location. Because of this, and because the major objective of drilling this site was to core the Neogene section, a presite survey was considered unnecessary. Consequently, the Elf-Aquitaine multichannel seismic Line WNC 109 (used for initial site selection) was intersected by the track of *Glomar Challenger* some 14 n. mi. southeast of the proposed drill site. Seismic Line WNC 109 then was followed to the site.

The ship averaged 10.6 knots for the 170.2 mi. transit, aided by favorable weather and currents.

The first of two positioning beacons was launched on the first pass at 2243 hr., 3 December 1982. A second beacon was required when the first proved to be too erratic for automatic positioning.

Site 587 (SW-8); South of Lansdowne Bank, Northern Lord Howe Rise

A special bottom-hole assembly (BHA) was assembled and checked for spacing to accommodate the latest version of the extended core barrel (XCB), a through-the-bit rotary coring tool, which was being deployed for the first time since Leg 84. The BHA was also configured to accommodate the conventional variable length HPC (VLHPC). By this means, piston coring to refusal could be followed immediately by rotary (XCB) coring to the objective without a pipe round trip to change bits.

Hole 587 was spudded at 1355 hr., 4 December 1982 with a mud line VLHPC core containing 3.1 m of calcareous ooze (Table 1). Drill pipe measured (DPM) depth of 1115 m from the rig floor reference elevation proved to be 4 m greater than the depth measured by the precision depth recorder (PDR).

All appeared well until Core 2 came up empty, apparently because the core catcher failed. Because the BHA was so near the mud line, a second shot was taken at Core 2, but very little core was recovered because of a mechanical failure in the VLHPC. This was quickly rec-

Table 1. Coring Summary, Site 587.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
1	4	1445	1115.1-1118.2	0.0-3.1	3.1	3.08	100
2	4	1800	1118.2-1127.8	3.1-12.7	9.6	9.51	99
3	4	1850	1127.8-1137.4	12.7-22.3	9.6	8.86	92
4	4	1940	1137.4-1147.0	22.3-31.9	9.6	9.71	100
5	4	2030	1147.0-1156.6	31.9-41.5	9.6	9.53	99
6	4	2120	1156.6-1166.2	41.5-51.1	9.6	9.58	100
7	4	2225	1166.2-1175.8	51.1-60.7	9.6	8.86	92
8	4	2305	1175.8-1185.4	60.7-70.3	9.6	9.82	100
9	4	0005	1185.4-1195.0	70.3-79.9	9.6	2.46	26
10	4	0045	1195.0-1204.6	79.9-89.5	9.6	9.54	96
11	4	0145	1204.6-1214.2	89.5-99.1	9.6	7.86	83
12	4	0400	1214.2-1218.7	99.1-103.6	4.5	tr	0
13	4	0630	1218.7-1223.7	103.6-108.6	5.0	CC	0
14	4	0800	1223.7-1233.3	108.6-118.2	9.6	0	0
15	4	0915	1233.3-1242.9	118.2-127.8	9.6	0	0
16	4	1015	1242.9-1252.5	127.8-137.4	9.6	tr	0
17	4	1110	1252.5-1262.1	137.4-147.0	9.6	0	0
					147.00	88.81	60.4%

tified, the tool was realigned for orientation, and coring continued with a third and successful attempt to obtain Core 587-2.

VLHPC coring in 9.5 m increments continued with good results until Core 587-12 (Table 1). At this point (99.1 m below the seafloor) a sudden change in lithology occurred as the sediment became brittle, coarse, and loosely cemented, compared to the fine, consolidated ooze encountered up to that point. Penetration of the corer fell off markedly and recovery dropped to mere traces. Virtually no usable core was recovered on VLHPC Cores 587-12 and 587-13.

The XCB was deployed for Cores 587-14 through 587-17. Despite all indications that the tool functioned properly, only traces of sediments could be found in the core barrel. Various penetration, flow rate, and core-catcher configurations were attempted but the coarse-grained carbonate sediments proved completely elusive. It could not be conclusively determined whether the core never entered the core liner or did enter but worked its way out during the retrieval.

Three Von Herzen heat-flow runs were made with essentially perfect results, including a good run on Core 587-12, despite the fact that no core was recovered when the tool was retrieved.

Kuster single-shot orientation shots were taken on each VLHPC core after Core 587-2. A high proportion of the photos were of a quality sufficient to derive useful magnetic orientation data.

The hole was terminated when it became apparent that only minimal scientific data were likely to be acquired and that we had reached a point of diminishing returns, especially in view of higher priorities at future sites. The pipe was tripped and the vessel got under way for Site 588 at 1505 hr., 6 December 1982.

LITHOSTRATIGRAPHY

Site 587 consists of one hole continuously cored with the hydraulic piston corer to a total sub-bottom depth of 147.0 m. Recovery was not complete and much of the sequence experienced severe coring disturbance. The recovered sequence is from one lithostratigraphic unit (Unit 1) of Quaternary to late Miocene age, but is composed of two lithofacies, a and b, that are interbedded throughout the length of the section.

The major lithofacies, a, is a foraminifer-bearing to foraminifer–nannofossil ooze. The percentages of foraminifers (Fig. 3) generally vary between about 5 and 50%. Calcareous nannofossils are abundant to dominant and nearly always make up greater than 50% of the sample. Detrital minerals are almost completely lacking with only a few small fragments of quartz, feldspar, and volcanic glass in some smear slides. Lithofacies a varies in color from white or very light gray to light bluish gray; there is no trend with depth. Throughout this lithofacies, there occasionally occur laminae, streaks, mottles, and small (1 mm) pockets of medium gray to very light gray disseminated inclusions of fine-grained authigenic iron sulfide (pyrite?) and chemical diffusion bands of medium and light medium gray. Burrows appear to be infrequent, but this may be due, in part, to the lack of good cores. The ooze is soft at the top of the sequence, becomes stiff by about 50 m sub-bottom, and by 90 m sub-bottom clasts of chalk occur.

The major lithofacies a is interbedded with a coarse-grained lithofacies b which consists of skeletal silty sands to skeletal sandy gravels. These interbeds are yellow gray and, less commonly, pinkish gray. The yellow gray color is distinctive and is principally derived from coaser silt, sand, and gravel-sized skeletal tests and fragments of planktonic and benthic foraminifers, calcareous red and green algae (including *Halimeda*), corals, bryozoa, and echinoid spines, as well as abundant, fine, indeterminate biogenic detritus and common skeletal carbonate lithoclasts (Fig. 4). The interbeds are massive or normally graded, subtly in the finer-grained deposits, and are typically less than 1 to 2 m thick. Clasts and irregular or disrupted layers of the foraminifer-bearing nannofossil ooze (or chalk) occur sporadically throughout the interbeds.

The occurrence of normal grading and shallow-marine biogenic detritus in the interbeds indicates that they are redeposited beds. However, interpretation is complicated by the fact that most of the skeletal debris occurs at or near the tops of cores, which may mean that some of these interbeds represent contamination from wash and cave-in during coring. Presumably, this material could be from the topmost 6 m of seabed, because Cores 587-1 and 587-2 are dominated by a disturbed sequence of coarse skeletal hashes of Pleistocene age (nannofossil Zone NN21).

Late Miocene chalk clasts and layers in Core 587-11 (89.5 to 99.1 m sub-bottom) appear to be stratigraphically *in situ* and represent episodes of sediment redeposition. The clasts are nannofossil-bearing chalks and include longer-ranging Neogene nannofossils and poorly preserved Cretaceous and Paleogene specimens (Table 2). The paleontologic evidence suggests reworking of the pre-Neogene nannofossils into an earlier Miocene ooze that subsequently became partially lithified, eroded, and redeposited into the late Miocene sequence. The chalk clast

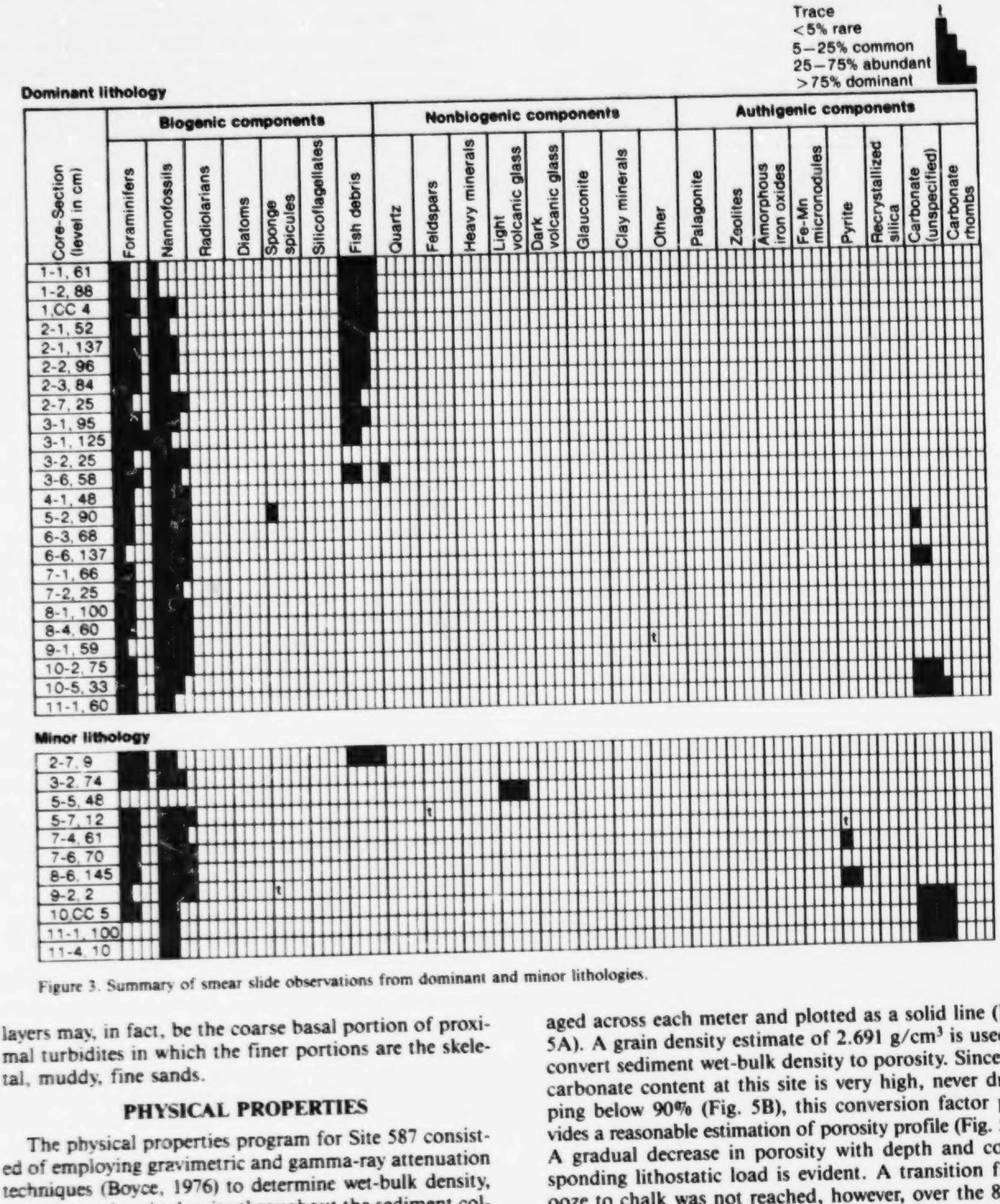

Figure 3. Summary of smear slide observations from dominant and minor lithologies.

layers may, in fact, be the coarse basal portion of proximal turbidites in which the finer portions are the skeletal, muddy, fine sands.

PHYSICAL PROPERTIES

The physical properties program for Site 587 consisted of employing gravimetric and gamma-ray attenuation techniques (Boyce, 1976) to determine wet-bulk density, porosity, and grain density throughout the sediment column. Carbonate content and thermal conductivity were also measured as functions of depth (see Explanatory Notes for details of methods). Plans to measure sonic velocity and to obtain specimens for shore-based permeability tests from a second hole were abandoned since coring of the adjacent hole was cancelled.

The GRAPE provides measurements of wet-bulk density versus depth. The distinct values (points) are averaged across each meter and plotted as a solid line (Fig. 5A). A grain density estimate of 2.691 g/cm^3 is used to convert sediment wet-bulk density to porosity. Since the carbonate content at this site is very high, never dropping below 90% (Fig. 5B), this conversion factor provides a reasonable estimation of porosity profile (Fig. 5C). A gradual decrease in porosity with depth and corresponding lithostatic load is evident. A transition from ooze to chalk was not reached, however, over the 89 m of core recovered. The physical properties for Site 587 are reported in detail by Morin (this volume).

SEISMIC STRATIGRAPHY

Figure 6 illustrates a portion of the shipboard water gun seismic profile collected during the approach to Site 587. Three acoustic units have been identified (A, B,

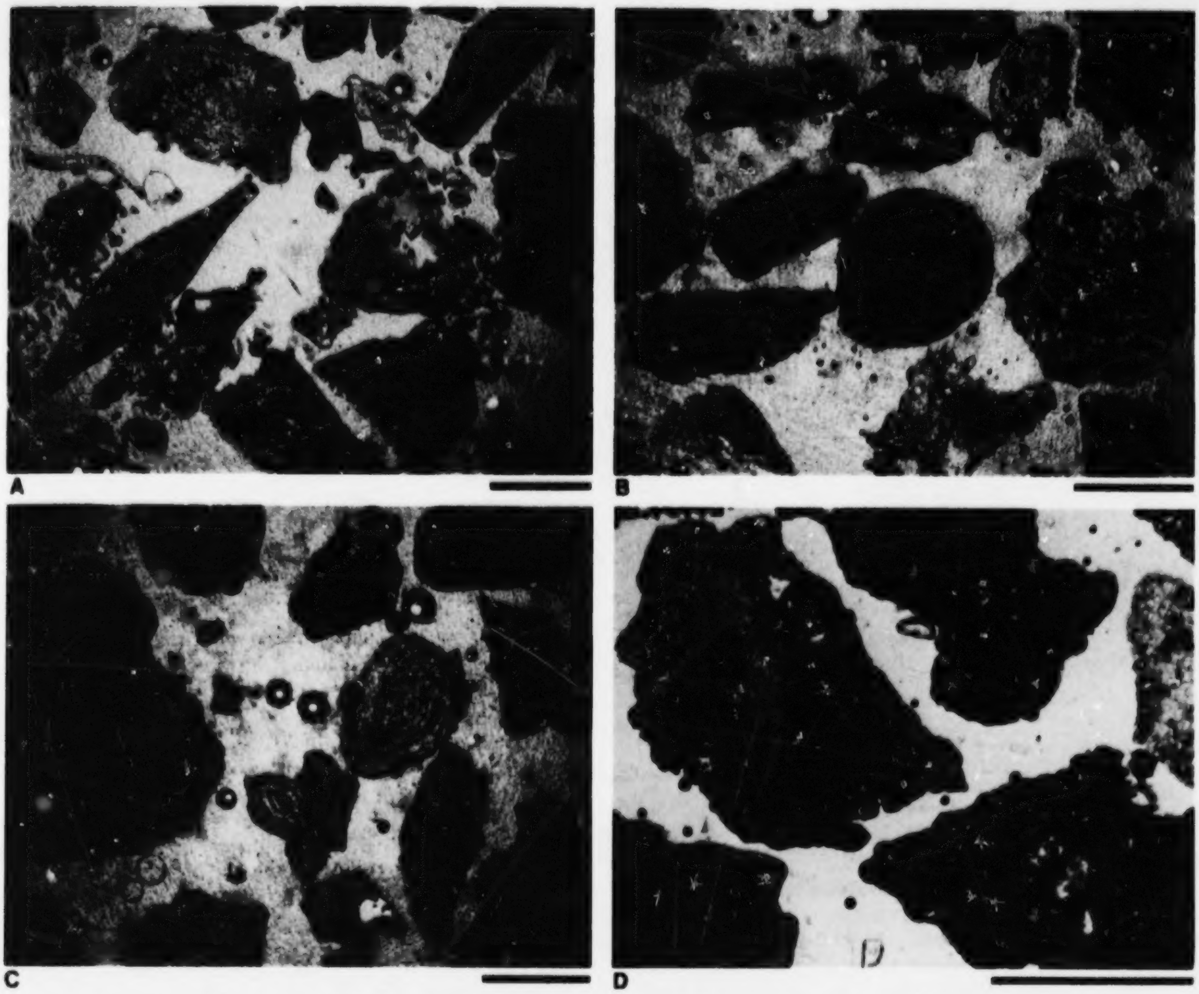

Figure 4. Photomicrographs of typical shallow-marine carbonate components in the redeposited coarse-grained sediment facies at Site 587. Plane polarized light, bar scale 1 mm. A. Dark *Halimeda* grains, lighter coral fragments, and large benthic foraminifers in Sample 587-1-2, 65-67 cm. B. Abraded grains of calcareous red and green algae, and bryozoan, coral, benthic foraminiferal, and irregular carbonate lithoclast material in 587-13,CC. C. Large bryozoan and dark *Halimeda*, coral, and benthic foraminiferal material in 587-13,CC. D. Irregular carbonate lithoclasts of skeletal packstone and wackestone in 587-13,CC.

and C). These are compared in part with the lithology of the site (Lithostratigraphic Unit I).

Acoustic Unit A is acoustically well stratified, characterized by relatively high amplitude and locally relatively coherent reflectors. The uppermost zone, in the region below the reflected wave-form down to 0.1 s,[3] is slightly more transparent than the underlying portion of Unit A. This upper zone also exhibits a possible buried channel adjacent to the drill site, and the sediment surface is dissected by an unfilled channel several miles to the east (Fig. 6). A diffuse zone of greater transparency is evident between 0.2 and 0.26 s sub-bottom. The lower boundary of Unit A grades down into Unit B.

Acoustic Unit B is more transparent than Unit A. The upper zone (0.325–0.45 s) is characterized by diffuse, noncoherent reflectors. Between 0.45 and 0.55 s sub-bottom, a well-defined transparent zone is evident.

Table 2. Some nannofossil species associated with chalk chunks from Section 587-11-1.

Species	Abundance	Preservation	Age
Coccolith sp. (small)	Common	Fair	
Coccolithus pelagicus	Few	Fair-poor	Cenozoic
Reticulofenestra pseudoumbilica	Rare	Fair	Neogene
Pontosphaera sp.	Rare	Poor	Cenozoic
Discoaster brouweri	Rare	Fair	Neogene
Helicosphaera carteri	Rare	Poor	Neogene
Sphenolithus abies	Rare	Fair	Neogene
Dictyococcites sp. cf. *D. scrippsae*	Few	Fair-poor	Paleogene
Scyphosphaera intermedia	Rare	Very poor	Cenozoic
Eiffellithus turriseiffeli	Rare	Very poor	Cretaceous
Watznaueria barnesae	Rare	Very poor	Cretaceous
Arkhangelskiella cymbiformis	Rare	Very poor	Cretaceous

Acoustic Unit C is separated from B by the uppermost of a series of strong, coherent reflectors which con-

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[3] Depths quoted in text as seconds below seafloor have been measured below Site 587.

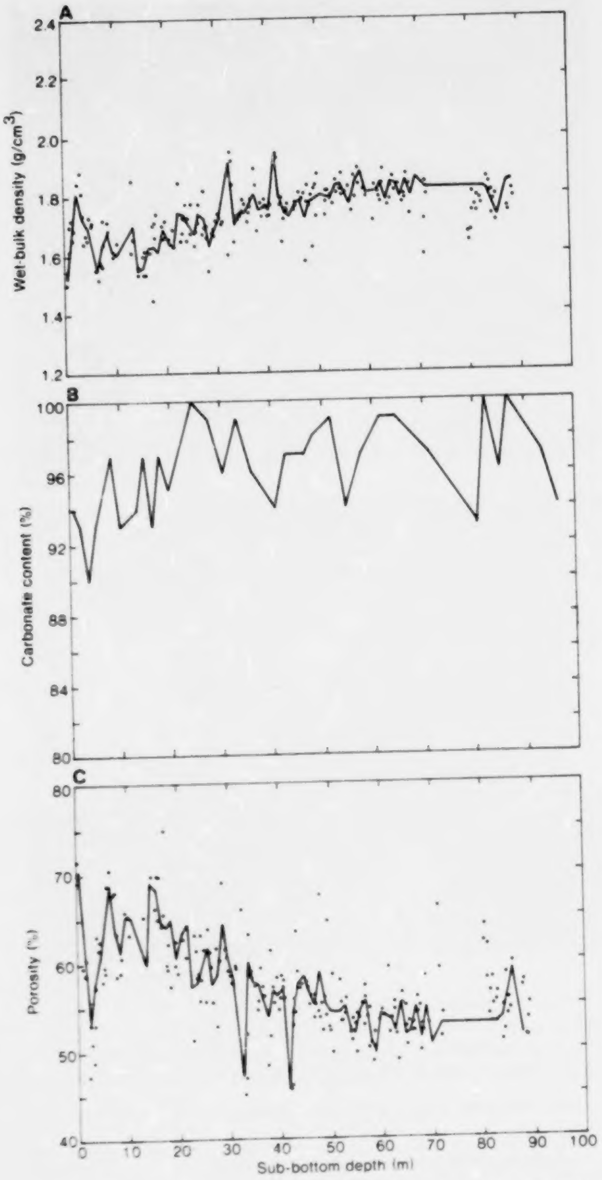


Figure 5. Physical properties versus sub-bottom depth for Site 587. A. GRAPE wet-bulk density. B. Carbonate content. C. GRAPE porosity.

stitute Unit C. Unit C at Site 587 continues below the limit of the figure.

Site 587 was drilled to a total depth of 147 m, within the uppermost portion of seismic Unit A. It comprises a single lithological unit (Unit I) of late Miocene to recent age, characterized by interbedded foraminifer-bearing to foraminifer-nannofossil ooze and skeletal sands to skeletal sandy gravels. The skeletal sands and gravels are reworked, perhaps as debris flows or turbidites from neighboring shallow banks. This coarse-grained facies appears to dominate the section in Cores 587-1 and 587-2 (Pleistocene) and from the lower portion of Core 587-10 at least through Core 587-11 (NN11, late Miocene). Below Core 587-12 to the bottom of the hole at Core 587-17 recovery was essentially zero, suggesting the presence of additional sand- and gravel-rich sections.

Correlation of the seismic and lithologic data suggests that the upper bioclastic sections (Cores 587-1 and 587-2) are genetically associated with the surficial and buried channels shown on Figure 6. These channels are probably Pleistocene features caused by episodes of redeposition during periods of low sea level. The zone of almost 100% core recovery in the calcareous-ooze-rich sequence (Cores 587-3 through 587-10, with the exception of 587-9) may correlate with the relatively transparent upper zone of seismic Unit A. The lower portion of the sequence (lowermost Core 587-10, possibly through 587-17) may correlate with the uppermost acoustically stratified portion of seismic Unit A, approximately 0.1 s sub-bottom.

BIOSTRATIGRAPHY

The preservation of planktonic foraminifers is reasonably good in the Pliocene-Pleistocene but deteriorates rapidly in the late Miocene; the faunal yield is disappointing, especially in the Pliocene and late Miocene, where zonal indicators are either absent or present only in low numbers. Benthic foraminiferal faunas are found to be mixtures of allochthonous and autochthonous species.

The sedimentation rate of sediments in the Pliocene and late Miocene was 24.5 m/m.y., decreasing upsection to 16.6 m/m.y. in the Quaternary.

The calcareous nannoplankton are abundant and moderately well preserved in the Quaternary through to the upper part of the late Miocene, but preservation and numbers deteriorate throughout the remainder of the late Miocene. No radiolarians, diatoms, or silicoflagellates were found in the smear slides.

Fish otoliths were recovered in Cores 1 to 3. Microfossil preservation was very poor in Core 3.

Calcareous nannoplankton zones and planktonic foraminiferal zones are correlated in Figure 7.

Foraminifers

Planktonic Foraminifers

The planktonic foraminifers from the 13 sediment cores containing material at this site represent a section from Pleistocene to upper Miocene. Only the fossils in the Pleistocene and Pliocene sediments are well preserved. Numbers and preservation of the planktonic foraminifers both deteriorate downward in the upper Miocene. The Neogene sequence at this site contains a mixture of tropical and temperate planktonic foraminiferal elements, providing a link between those of the tropical Site 586 (289) and the cooler water faunas of the sites drilled further south (Site 588, 590, 591, 592, 593, and 594).

A detailed analysis of the faunas reveals that Blow's (1969) zonal scheme cannot be used for the site because of the scarcity of index planktonic foraminifers in the

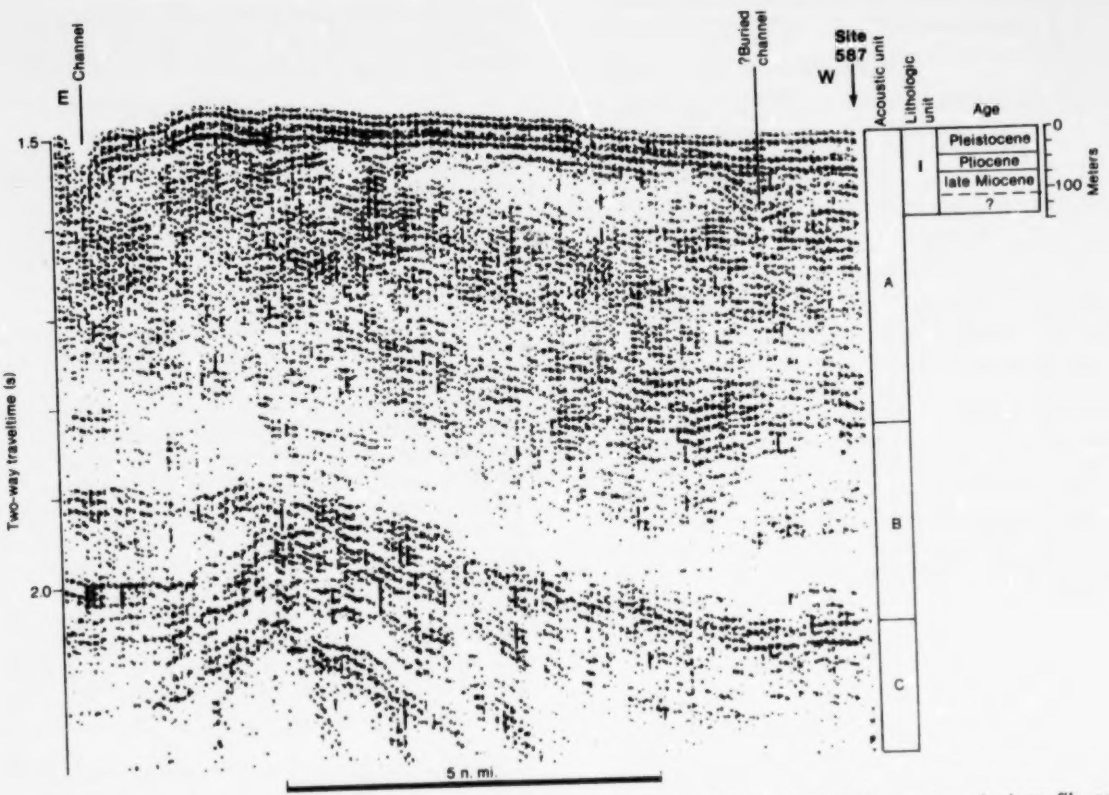


Figure 6. Comparison of acoustic Units A–C with Lithostratigraphic Unit I cored at Site 587; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 2000 m/s.

Pleistocene and Pliocene sequence. Tropical elements dominate in the late Miocene, whereas temperate elements dominate in the Pliocene–Pleistocene sequence, although many tropical elements persist. Thus, biostratigraphic subdivision of the late Miocene requires use of the tropical zones (Srinivasan and Kennett, 1981a), whereas the Pliocene–Pleistocene sequence requires the use of the temperate zones of Kennett (1973). The zonal scheme employed at the site is shown in Figure 7. The *Globorotalia truncatulinoides* Zone in Sample 587-1-1, 5–6 cm through 587-3-2, 19–20 cm yielded a well-preserved, highly diverse fauna which includes the zone fossil, *G. truncatulinoides, Pulleniatina obliquiloculata, G. tumida*, and *G. inflata*. Reworked Pliocene foraminifers are detectable in 587-1,CC and in other samples.

Samples 587-3-3, 19–20 cm through 587-4,CC yielded faunas of *Globorotalia truncatulinoides–G. tosaensis* overlap Zone, which yielded the zone fossils, *G. truncatulinoides, G. tosaensis, G. menardii*, and *Sphaeroidinella dehiscens*. In the lower part of the zone *Globigerinoides fistulosus*, a late Pliocene index form, occurs in association with *Globorotalia truncatulinoides*.

The *G. tosaensis* Zone in Sample 587-5-1, 114–115 cm through 587-5-4, 90–91 cm yielded the zone fossil in a highly diverse fauna, which also includes *P. obliquiloculata, G. menardii, G. inflata, G. puncticulata, G. crassaformis*, and rare *Globigerinoides fistulosus*.

Planktonic foraminiferal determinations place the Pleistocene/Pliocene boundary between Samples 587-4,CC and 587-5-1, 114–115 cm. The boundary is drawn at the first evolutionary appearance of *Globorotalia truncatulinoides*.

The *G. inflata* Zone, from Sample 587-5-5, 80–81 cm through 587-5,CC, yielded a nicely preserved, well-diversified fauna, which includes the zone fossil, *G. menardii, G. multicamerata, G. crassaformis, G. tumida*, and *P. obliquiloculata*.

The *G. crassaformis* Zone, which was identified in Sample 587-6-1, 85–86 cm through 587-6-3, 89–90 cm, yielded a rich fauna. *Globigerina nepenthes* and *Globorotalia* cf. *miotumida* make their last appearance in the lower part, and *G. margaritae* is present in the upper part of the zone. The first appearance of *S. dehiscens* is in the upper part of the zone, and is much later than at the tropical Site 289 (Kennett, 1973; Srinivasan and Kennett, 1981a,b).

Samples 587-6-4, 85–86 cm through 587-6-5, 85–86 cm yielded faunas of the *Globorotalia puncticulata* Zone, which include the zone fossil, *P. primalis, G.* cf. *miotumida, G. tumida tumida, G. menardii*, and *G. multicamerata*. The base of the zone is marked by the first appearance of *G. puncticulata*. As was true for the warm subtropical sites, the evolutionary bioseries is not represented.

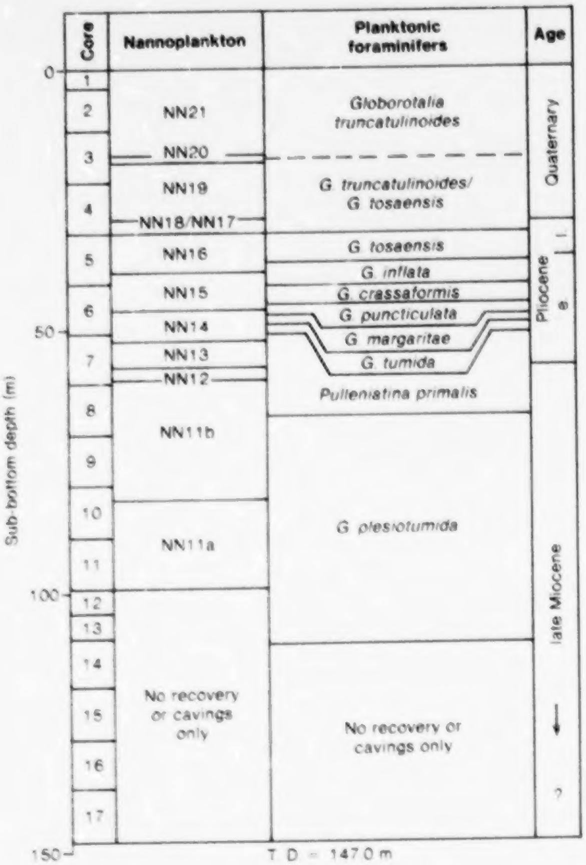


Figure 7. Biostratigraphy of Hole 587.

The *Globorotalia margaritae* Zone was identified in Sample 587-6-6, 53–56 cm and 587-6-6, 124–125 cm; it yields the zone fossil in association with *G.* cf. *miotumida*, *G. tumida tumida*, and *P. primalis*.

The *Globorotalia tumida* Zone (= N18) is represented in Samples 587-6-7, 11–12 cm through 587-6,CC, which yielded an excellent fauna including the zone fossil, *Globigerina nepenthes*, *Globorotalia menardii*, *Dentoglobigerina altispira*, and *P. primalis*.

The Miocene/Pliocene boundary is placed between Samples 587-6,CC and 587-7-1, 59–60 cm; the boundary is drawn at the first evolutionary appearance of *Globorotalia tumida tumida*.

The *Pulleniatina primalis* Zone (= N17B) is recorded from Sample 587-7-1, 59–60 cm through 587-8-4, 70–71 cm which again yielded reasonable faunas, including the zone fossil, *G. miotumida*, *Orbulina bilobata*, *G. plesiotumida*, *Neogloboquadrina acostaensis*, and *G. cibaoensis*.

The *G. plesiotumida* Zone (= N17a) is represented in the interval from Samples 587-8-5, 70–71 cm through 587-13,CC. The faunas in these samples besides the zone fossil, include *G. miotumida*, *G. multicamerata*, *Globigerina nepenthes*, and *N. acostaensis*. *Candeina nitida* makes its first appearance in Sample 587-10-6, 17–18 cm, and *Globoquadrina dehiscens* makes its last appearance within the zone (Sample 587-10-5, 17–18 cm).

Benthic Foraminifers

Benthic foraminifers were examined in core-catcher Samples 587-1-9,CC and 587-10-13,CC from the fraction of the sediment greater than 63 µm. Each fauna contains an allochthonous and an autochthonous element; the allochthonous benthics are considered to be derived from a carbonate platform back-reef to beach environment.

Allochthonous benthic foraminifers and some other invertebrates are most common in Cores 587-1 through 587-3 and 587-10 through 587-13, in which few if any bathyal species are present. Typical constituents of this element are bryozoa, heavily spinose ostracodes, numerous miliolids including ornamented quinqueloculinids, and *Articulina scrobiculata*, *Tretomphalus pacificus*, *Uvigerina porrecta*, *Elphidium macellum*, *E. crispum*, and *E.* cf. *advenum*, *Amphistegina* sp., *Cymbaloporella* sp., and several larger benthic genera. Considering the amount of carbonate debris in each core-catcher sample, it appears that the depositional mode changed from the Miocene (Cores 587-10 through 587-13), characterized by large, pure shallow-water deposits, to the upper Pliocene–Pleistocene (Cores 587-5 through 587-1), which is characterized by redeposited shallow-water elements within marl deposit.

Miocene faunas (Cores 587-7 through 587-9) include *Laticarinina bullbrooki*, *Uvigerina auberiana*, *Cibicidoides bradyi*, *Osangularia culter*, *Gyroidinoides nitidula*, *Bulimina alazanensis*, and *Robulus nicobarensis*, as well as many long-ranging species listed below in the discussion about the Quaternary.

Within the Pliocene (Cores 587-5 and 587-6), faunas can be differentiated into glacial (Core 587-5) and preglacial (Core 587-6). Faunas of Core 587-5 resemble those of the Pleistocene, except that they are rarer and more difficult to separate from the chalky matrix. The preglacial faunas of Core 587-6 contain taxa typical of the Miocene at this site; several of them, such as *Rectuvigerina multistriata*, *Bolivina subaenariensis*, *C. cicatricosus*, and *Heterolepa kullenbergi*, do not range above Core 587-6.

Quaternary autochthonous faunas (Core 587-1 through Sample 587-4,CC) contain many long-ranging, cosmopolitan species such as *Karreriella bradyi*, *Globocassidulina subglobosa*, *Cibicides wuellerstorfi*, *Cassidulina crassa*, *Sigmoilopsis schlumbergeri*, *Stilostomella lepidula*, *U. hispida*, *Bulimina striata*, and *Ehrenbergina pacifica*. Species are considered to be autochthonous if they are common in Cores 587-7 through 587-9, which contain much less evidence of redeposited carbonates, if they appear consistently in sediments from the deeper Site 586, and if they are known from the bathyal zone in others areas.

Comparison of the faunas at Site 586 (closer to 2200 m) and Site 587 (1101 m) indicate that the following species are restricted to the shallower site: *R. multistriata*, *Robulus nicobarensis*, *E. pacifica*, *S. raphanus*, *U. nitidu-*

la, and *O. culter. Osangularia bengalensis, B. pusilla, Sphaeroidina bulloides, Pullenia quinqueloba*, among others, were found at the deeper Site 586, but not at Site 587.

Calcareous Nannoplankton

Samples from Cores 1 through 9 contain abundant moderately to well-preserved nannoplankton. Samples below 587-10,CC contain rare to few poorly preserved nannoplankton. The boundary between NN21 and NN20 was not observed, but all other zones down to NN11a are present.

Pleistocene

The presence of *Emiliania huxleyi* in Samples 587-1-1, 4-5 cm to 587-3-3, 20-21 cm places these samples in the late Pleistocene *Emiliania huxleyi* Zone (NN21). The rare occurrence of *Discoaster brouweri, D. pentaradiatus*, and *Ceratolithus rugosus* in Sample 587-1,CC is interpreted as reworked late Pliocene. The presence of *E. ovata* and the absence of *Calcidiscus macintyrei* in Samples 587-3-4, 20-21 cm to 587-4-4, 4-5 cm place these samples in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The missing *Gephyrocapsa oceanica* Zone (NN20) may be present between Samples 587-3-3, 20-21 cm and 587-3-4, 20-21 cm. The presence of *E. ovata* and *C. macintyrei* in Sample 587-4-5, 4-5 cm places this sample in the lower subzone in the *E. ovata* Zone (NN19a).

Pliocene

The presence of *Discoaster brouweri* and absence of *D. pentaradiatus* in Sample 587-4-6, 4-5 cm place this sample in the late Pliocene *Discoaster brouweri* Zone (NN18). Sample 587-4,CC contains *D. pentaradiatus* with *D. brouweri*, placing it in the late Pliocene *D. pentaradiatus* Zone (NN17). The last occurrence of *D. surculus* in Sample 587-5-1, 106-107 cm places Samples 587-5-1, 106-107 cm to 587-5-5, 4-5 cm in the late Pliocene *D. surculus* Zone (NN16).

The presence of *Reticulofenestra pseudoumbilica* and the absence of *Amaurolithus tricorniculatus* in Samples 587-5-6, 4-5 cm to 587-6-4, 4-5 cm place these samples in the early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). Samples 587-6-5, 4-5 cm to 587-7-1, 4-5 cm contain *A. tricorniculatus* together with *D. asymmetricus*, which places these samples in the early Pliocene *D. asymmetricus* Zone (NN14). The presence of *Ceratolithus rugosus* and the absence of *D. asymmetricus* in Samples 587-7-2, 4-5 cm and 587-7-3, 4-5 cm place this interval in the early Pliocene *Ceratolithus rugosus* Zone (NN13). The absence of *C. rugosus* in Sample 587-7-4, 4-5 cm places this sample in the early Pliocene *Amaurolithus tricorniculatus* Zone (NN12).

Miocene

Samples 587-7-5, 4-5 cm to 587-10-1, 12-13 cm contain *Discoaster quinqueramus* along with *A. primus*, which places the samples in the upper subzone of the late Miocene *Discoaster quinqueramus* Zone (NN11b).

Samples 587-10,CC and 587-11,CC are recrystallized and cannot be assigned an age. Sample 587-16,CC is composed of a yellow and a gray fraction. The gray fraction is interpreted as downhole caving from lower Pleistocene (NN19) sediments, the yellow sediments are probably upper Miocene.

Diatoms and Silicoflagellates

Neither fossil group was encountered during routine shipboard smear slide investigation.

Radiolarians

Radiolarians were not noted in the upper Neogene and Quaternary sediments of Hole 587.

PALEOMAGNETISM

Shipboard long-core measurements of the horizontal component of NRM were made on Cores 587-1 through 587-7 at 10-cm intervals. Subsequent laboratory (cryogenic) measurements were made on two specimens per section for Cores 3 through 10. The uppermost two cores were fluid. Cores 587-3 and 587-4 were partly fluid and moderately deformed during drilling. Shipboard interpretation of the long-core declination data was found to be inconsistent with the laboratory results, presumably because the core liner was contaminated and because of the high scatter in directions of these extremely weakly magnetized sediments:

Geometric mean intensity = 0.054 μG
Scalar mean inclination = $-5.9 \pm 43°$ s.d.
Axial dipole inclination = $-37.8°$

A relatively high intensity zone (typically 0.7 μG) occurred at the top of the sequence above Section 587-5-5, and correlates with the presence of skeletal carbonate. Below Section 587-5-6, intensities dropped to very low values. Prominent intensity spikes occurred at the following depths:

Core-Section (level in cm)	Depth (m)	Intensity (μG)
6-3, 25	44.75	0.131
8-6, 17	68.37	0.113
10-2, 25	81.65	0.367
10-5, 100	86.90	1.109

Within the uppermost high-intensity zone, directions of remanence appear to be serially correlated, but are considered to be unreliable because the sediments were disturbed. In the very weakly magnetized zone below, NRM directions were too scattered to give a reliable magnetic stratigraphy. Measurements were repeatable within a few tens of degrees, so the scatter cannot be attributed to instrumental noise. Viscous overprinting does not appear to be serious because the mean inclination ($-5.9°$) is close to zero. It seems probable that some of the scatter is due to a secondary chemical remanence associated with the reduction of iron oxides to iron monosulfides (pyrite blebs were common in this sequence).

SEDIMENTATION RATES

Only the upper part of Site 587 can be used for determining sedimentation rates (Fig. 8), because of zero recovery and caving below Core 587-10.

Quaternary (Cores 587-1 through 587-4) sedimentation rates are 16.6 m/m.y. in foraminifer-bearing nannofossil ooze, which is apparently interbedded with ske-

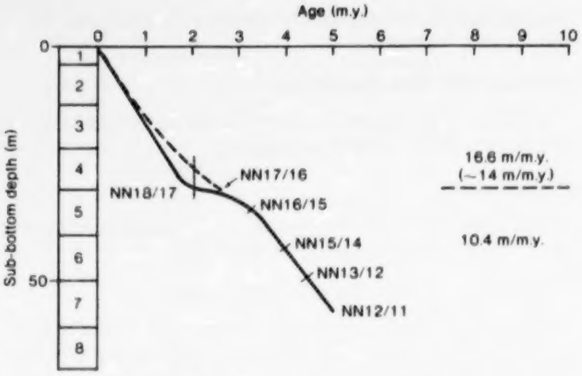


Figure 8. Sedimentation rates at Site 587 based on nannofossil data. Rates not determined below Core 7.

letal silty sand to skeletal sandy gravel. However, most of the coarser material occurs at the tops of cores, and it may represent material which caved in from the upper Quaternary sediments of Core 587-1. If so, the Quaternary sedimentation rate may not exceed 14.0 m/m.y. (dashed line in Fig. 8).

Below Samples 587-4,CC the sedimentation rate is 10.4 m/m.y. in foraminifer-bearing nannofossil oozes of Pliocene age.

No datum levels could be distinguished in the upper Miocene skeletal oozes and chalks, and sedimentation rates could not be extrapolated.

SUMMARY AND CONCLUSIONS

Site 587 is located on the southern slope of Lansdowne Bank in the southwest Pacific at 21°S, 161°E. The main objective at Site 587 was to obtain a complete Neogene sequence by hydraulically piston coring the upper Neogene sediments to refusal and then rotary coring through the remaining sequence. This site was selected to obtain an uncomplicated, high-resolution record in calcareous sediments of Neogene age between the warm subtropics and the equator. These objectives were largely not met because sandy layers in the upper Miocene sediments prevented core recovery. Nevertheless, a useful latest Miocene through Quaternary record was recovered using the HPC to 99 m. The remaining part of the sequence, to the bottom of the hole at 147 m, recovered only traces of skeletal sandy gravel of probable late Miocene age. All of the Quaternary through late Miocene planktonic foraminiferal and nannoplankton zones are present at Site 587 (Fig. 9).

The recovered sequence is from one lithostratigraphic unit but is composed of two lithofacies (Fig. 9). The major lithofacies is of pelagic origin and is a foraminifer-bearing to foraminifer-nannofossil ooze. The minor lithofacies is a coarse-grained sediment consisting of skeletal silty sands to skeletal sandy gravels. This dominates the upper Quaternary and occurs as thinner interbeds in the upper Miocene.

Calcareous nannofossils nearly always make up more than 50% of the pelagic facies, whereas foraminifers mostly vary between 5 and 50%. Detrital minerals are almost completely lacking. The ooze is soft at the top of the sequence and becomes stiff by about 50 m sub-bottom; by 90 m there occur clasts of indurated chalk.

The coarse sediment facies is formed of redeposited sediments of shallow-water origin, especially corals, calcareous algae, bryozoa, and shallow-water foraminifers from the photic zone of nearby banks. A majority of these particles exhibit surface wear, which probably occurred in shallow water and before redeposition. The interbeds are massive or normally graded and are typically less than 1 to 2 m thick. A few of these layers are found at the tops of cores and thus may represent contamination from wash and caving during coring, presumably from the Quaternary sands. The upper Miocene coarse layers appear to be in place.

Because the coarser redeposited facies occurs in the late Quaternary and probably the late Miocene, which are times of sea level regression, it is suggested that sediment gravity flows or turbidity currents were locally stimulated at times of low sea level stands. The sedimentation rate for the Pliocene was 10.4 m/m.y., increasing to 16.6 m/m.y. during the Quaternary. The relatively low rate during the Quaternary is surprising considering the coarser bioclastic sediment facies. One possible explanation for this could be channeling and localized erosion of sediments by turbidity currents, as suggested by nearby channel structures observed on the seismic profile (see Seismic Stratigraphy). The zone of almost 100% core recovery in the carbonate-ooze-rich sequence is inferred to correlate with an upper, relatively transparent zone of seismic Unit A. The lower sand-rich part of the sequence may correlate with a further acoustically stratified section of Unit A.

Three successful heat flow measurements provide a linear temperature profile of 5.47°C/100 m.

REFERENCES

Blow, W. H., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In* Brönnimann, P., and Renz, H. H. (Eds.), *Proc. 1st Int. Conf. Planktonic Microfossils, Geneva, 1967:* Leiden (E. J. Brill), pp. 197-421.

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Kennett, J. P., 1973. Middle and late Cenozoic planktonic foraminiferal biostratigraphy of the southwest Pacific, DSDP Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 575-639.

Launay, J., Dupont, J., Lapouille, A., Ravenne, C., and de Broin, C. E., 1977. Seismic traverses across the northern Lord Howe Rise and comparison with the southern part (southwest Pacific). *Int. Symp. Geodynamics Southwest Pacific, Noumea (New Caledonia):* Paris (Editions Technip), pp. 155-164.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific* (map). Scripps Institution of Oceanography, La Jolla, California, IMR Technical Reports ANB.

Ravenne, C., de Broin, C. E., Dupont, J., Lapouille, A., and Launay, J., 1977. New Caledonia Basin-Fairway Ridge: structural and sedimentary study. *Int. Symp. Geodynamics Southwest Pacific, Noumea (New Caledonia)*, pp. 145–154.

Srinivasan, M. S., and Kennett, J. P., 1981a. A review of Neogene planktonic foraminiferal biostratigraphy: Applications in the equatorial and South Pacific. *In* Warme, J. E., Douglas, R. G., Winterer, E. L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress*. Soc. Econ. Paleontol. Mineral., Spec. Publ., 32:395–432.

_______, 1981b. Neogene planktonic foraminiferal biostratigraphy and evolution: Equatorial to sub-Antarctic, South Pacific. *Mar. Micropaleontol.*, 6:499–533.

Date of Acceptance: 1 December 1983

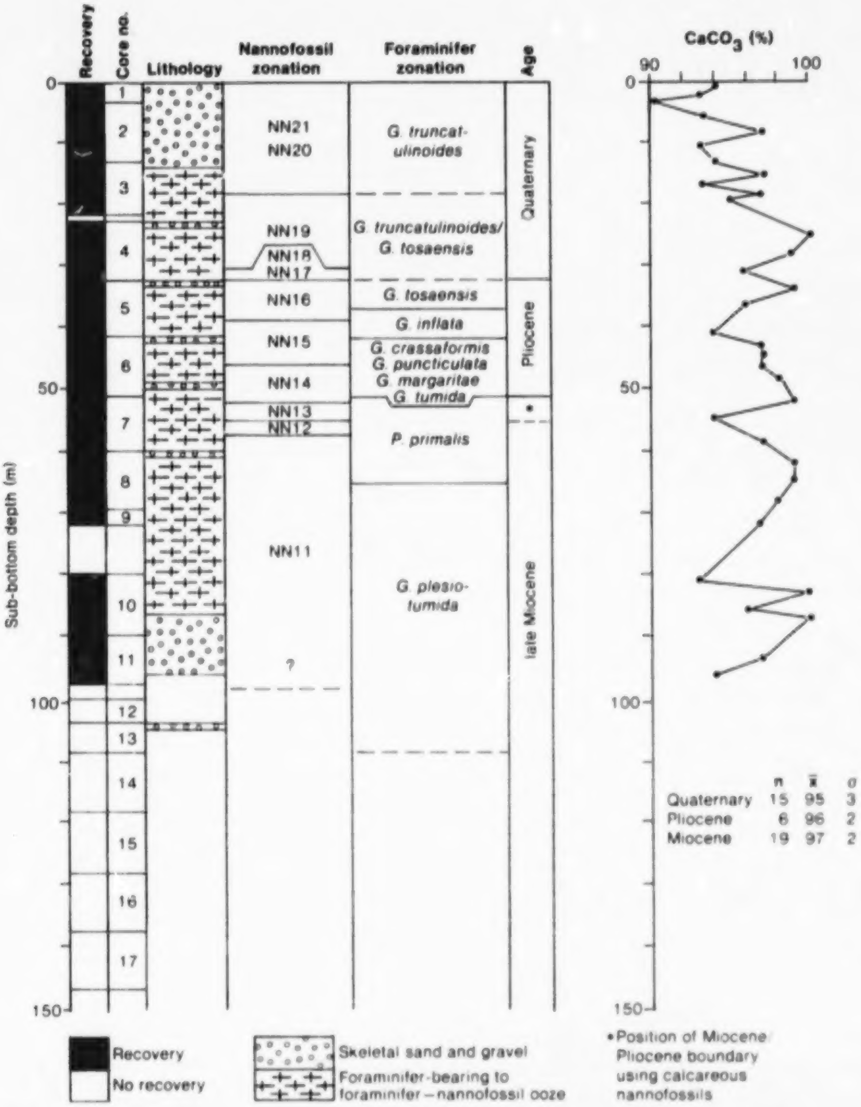
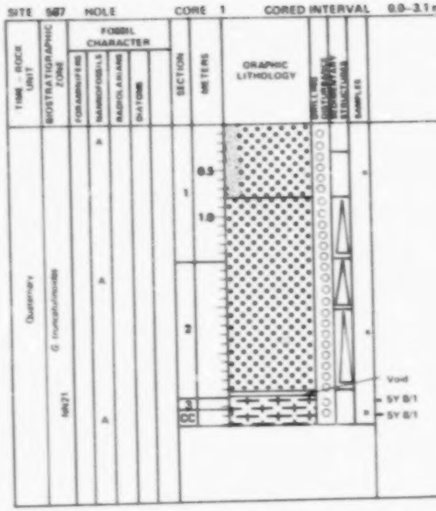


Figure 9. Summary lithology, biostratigraphy, and calcium carbonate percentages for Site 587.

SITE 587 HOLE CORE 1 CORED INTERVAL 0.0–3.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN21
A
A
A
1
2
3
CC
0.5
1.0
Void
5Y 8/1
5Y 8/1

LITHOLOGIC DESCRIPTION

SKELETAL SANDY FORAMINIFER NANNOFOSSIL OOZE, pinkish gray (5YR 8/1), soft to soupy, massive, with redeposited shallow marine skeletal fragments. Disturbed by coring.

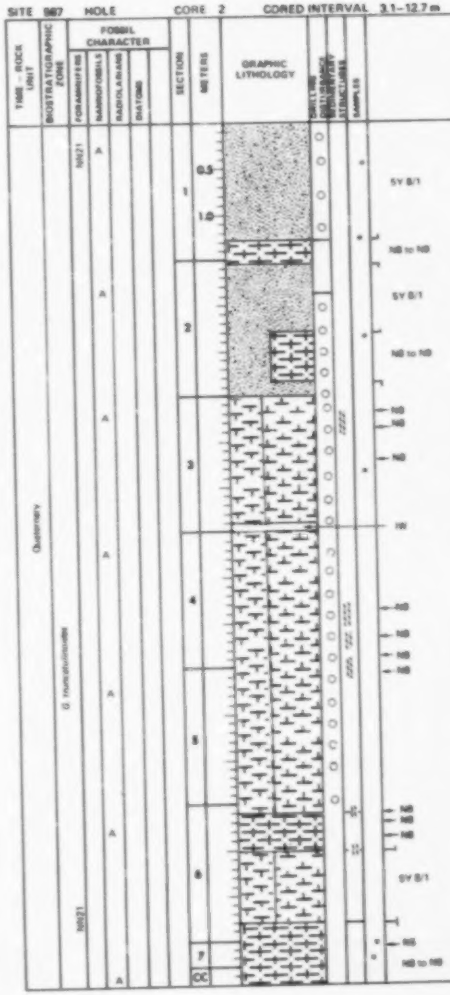
SKELETAL SILTY SAND TO SKELETAL SANDY GRAVEL, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), soft to firm, massive to graded. Normal grading may be from core disturbance. Shallow marine skeletal fragments include coral, green algal, and large foraminifers.

FORAMINIFER-BEARING NANNOFOSSIL OOZE TO FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8) to white (N9), soft, with disrupted pyritized laminae and blebs, rare burrows and chemical diffusion bands.

SMEAR SLIDE SUMMARY

	1, 61 D	2, 98 D	CC, 4 D
Texture:			
Sand	C	D	–
Silt	C	C	A
Clay	D	–	A
Composition:			
Carbonate unspec.	D	D	D
Foraminifers	C	C	A
Calc. nannofossils	R	R	A

SITE 587 HOLE CORE 2 CORED INTERVAL 3.1–12.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN21
NN21
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
N8 to N9
5Y 8/1
N8 to N9
N9
N9
N9
N9
N9
N9
N9
N9
N9
N9
N9
5Y 8/1
N8
N8 to N9

LITHOLOGIC DESCRIPTION

SKELETAL SILTY SAND TO SKELETAL SANDY GRAVEL, yellowish gray (5Y 8/1) to pinkish gray (5YR 8/1), soft to firm, massive to graded, latter may be from core disturbance, includes shallow marine skeletal fragments.

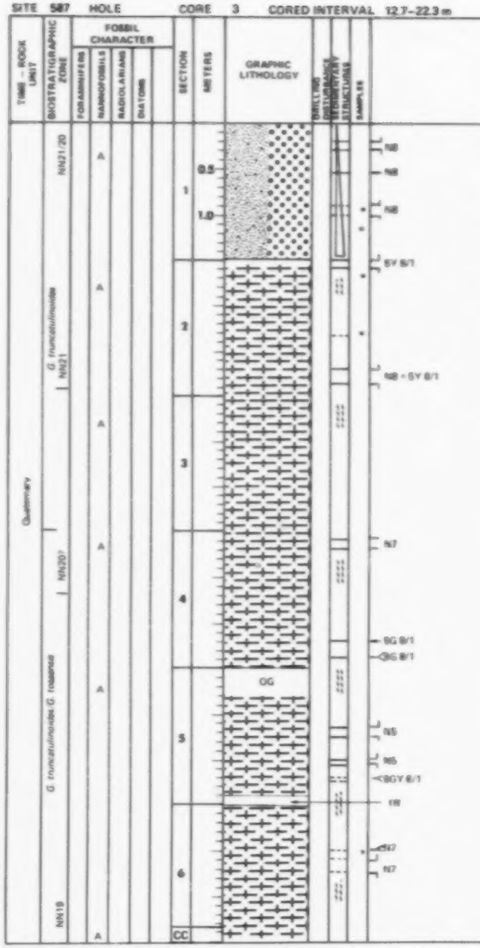
FORAMINIFER-BEARING NANNOFOSSIL OOZE TO FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8) to white (N9), soft, with disrupted pyritized laminae and blebs, rare burrows and chemical diffusion bands.

NANNOFOSSIL-BEARING FORAMINIFER OOZE, yellowish gray (5Y 8/1), soft, massive, includes chunks of light gray (N8) foraminifer nannofossil ooze with blurred contacts with host ooze. Significant core disturbance down to Section 5.

SMEAR SLIDE SUMMARY

	1, 92 D	1, 137 D	2, 98 D	3, 84 D	7, 9 M	7, 25 D
Texture:						
Sand	C	C	C	C	A	–
Silt	D	D	A	D	A	C
Clay	C	C	A	C	C	D
Composition:						
Carbonate unspec.	D	A	A	A	A	C
Foraminifers	C	A	A	A	A	C
Calc. nannofossils	C	A	A	C	C	D

SITE 587 HOLE CORE 3 CORED INTERVAL 12.7–22.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21/20
G. truncatulinoides
NN21
NN20?
G. truncatulinoides/G. tosaensis
NN19
A
1
2
3
4
5
6
CC
0.5
1.0
OG
N8
N8
N8
5Y 8/1
N8 + 5Y 8/1
N7
5G 8/1
5G 8/1
N5
N5
5GY 6/1
N7
N7

LITHOLOGIC DESCRIPTION

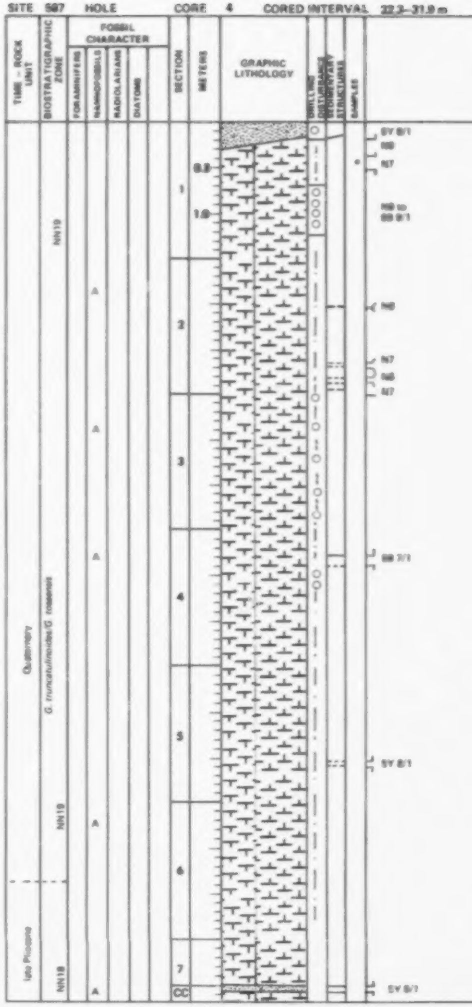
SKELETAL SILTY SAND TO SKELETAL SANDY GRAVEL, yellowish gray (5Y 8/1), firm, massive, with very light gray (N8) lumps and laminae. Appears normally graded but may be all disturbed by coring.

FORAMINIFER-BEARING NANNOFOSSIL OOZE TO FORAMINIFER NANNOFOSSIL OOZE, very light gray (N8), soft, massive, with disrupted pyritized laminae and blebs, rare burrows and chemical diffusion bands.

SMEAR SLIDE SUMMARY:

	1, 95	1, 125	2, 25	6, 50	2, 74
	D	D	D	D	M
Texture:					
Silt	D	D	C	A	A
Clay	C	C	D	A	A
Composition:					
Quartz	–	–	–	R	–
Foraminifers	A	D	C	A	A
Calc. nannofossils	A	C	D	A	A
Other	A	C	–	C	–

SITE 587 HOLE CORE 4 CORED INTERVAL 22.3–31.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
late Pliocene
NN19
G. truncatulinoides/G. tosaensis
NN19
NN18
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
N9
N7
N9 to 5B 9/1
N8
N7
N8
N7
5B 7/1
5Y 8/1
5Y 8/1

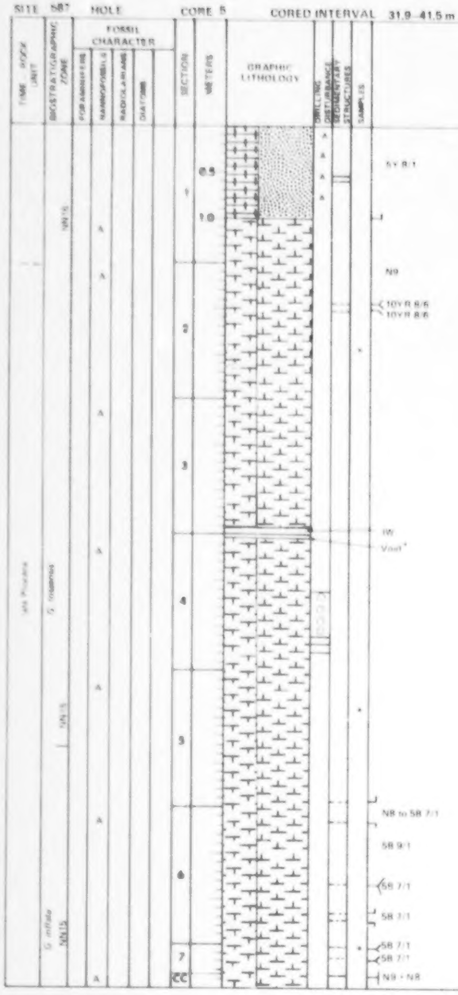
LITHOLOGIC DESCRIPTION

SKELETAL MEDIUM TO COARSE SAND, yellowish gray (5Y 8/1), very disturbed by coring.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to bluish white (5B 9/1), greenish gray laminae at 48 cm may be altered volcanic ash. Pyrite(?) occurs in disrupted pods throughout core. Interbeds may be present but very disturbed. Entire core has appearance of severe coring disturbance.

SMEAR SLIDE SUMMARY:

	1, 48
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D


SITE 587 HOLE CORE 5 CORED INTERVAL 31.9–41.5 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
NN15
G. inflata
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
5Y 8/1
N9
10YR 8/6
10YR 8/6
IW
Void*
N8 to 5B 7/1
5B 9/1
5B 7/1
5B 7/1
5B 7/1
5B 7/1
N9 – N8

LITHOLOGIC DESCRIPTION

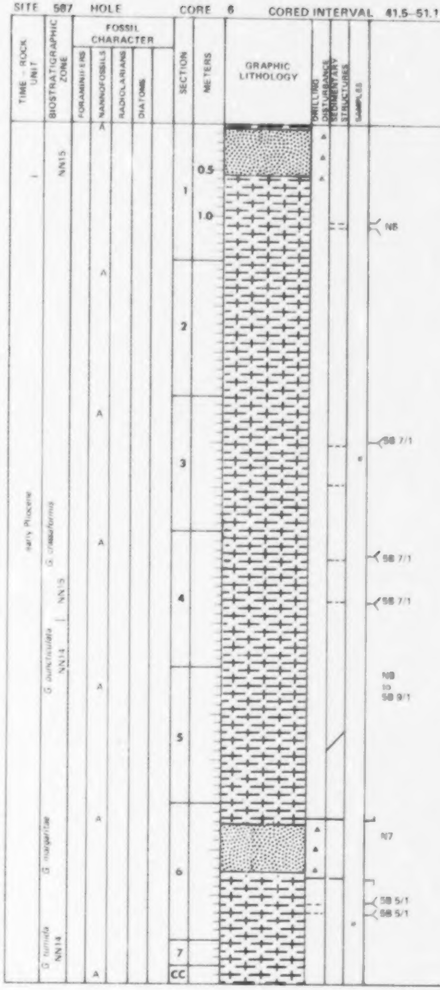
SKELETAL CHALK SAND, yellowish gray (5Y 8/1) hard breccia created by coring. Homogeneous with a few scattered pods of medium bluish gray (5B 5/1).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to light bluish gray (5B 7/1) by Section 6. Homogeneous except for a few scattered bands and laminae. Soft in Section 1 but stiff from Sections 2 through 7. Sections 6 and 7 show color laminae. Pod of clear volcanic glass at Section 5, 48 cm.

*Artificial gap due to core handling.

SMEAR SLIDE SUMMARY

	2, 90	5, 48	7, 12
	D	M	M
Composition:			
Feldspar	–	–	T
Volcanic glass	–	A	–
Carbonate unspec.	C	–	–
Foraminifers	C	–	C
Calc. nannofossils	D	–	D
Sponge spicules	R	–	–


SITE 587 HOLE CORE 6 CORED INTERVAL 41.5–51.1 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
G. crassaformis
NN15
NN14
G. puncticulata
G. margaritae
G. tumida
NN14
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5B 7/1
5B 7/1
5B 7/1
N8 to 5B 9/1
N7
5B 5/1
5B 5/1

LITHOLOGIC DESCRIPTION

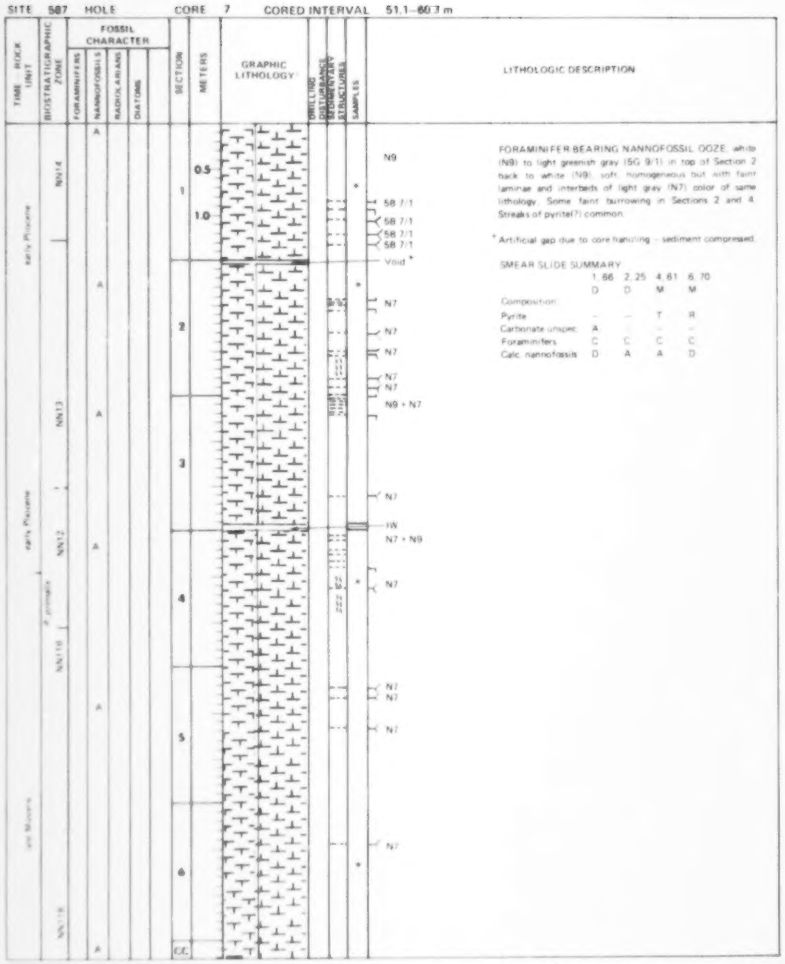
SKELETAL CHALK SAND, light yellowish gray (5Y 9/1), coring breccia in Section 1, may be slump in Section 6.

FORAMINIFER-BEARING NANNOFOSSIL OOZE TO NANNOFOSSIL OOZE, white (N9), stiff, with interbeds of very light gray (N8) and light bluish gray (5B 7/1) coloring. Contacts are gradational. Specks of pyrite(?) in Section 7 and Core Catcher.

SMEAR SLIDE SUMMARY

	3, 88	6, 137
	D	D
Composition:		
Carbonate unspec.	A	–
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 587 HOLE CORE 7 CORED INTERVAL 51.1–60.7 m


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
NN14
NN13
NN12
P. primalis
NN11B
A
0.5
1.0
1
2
3
4
5
6
CC
Void*
N9
5B 7/1
N7
N9 + N7
IW
N7 + N9

LITHOLOGIC DESCRIPTION

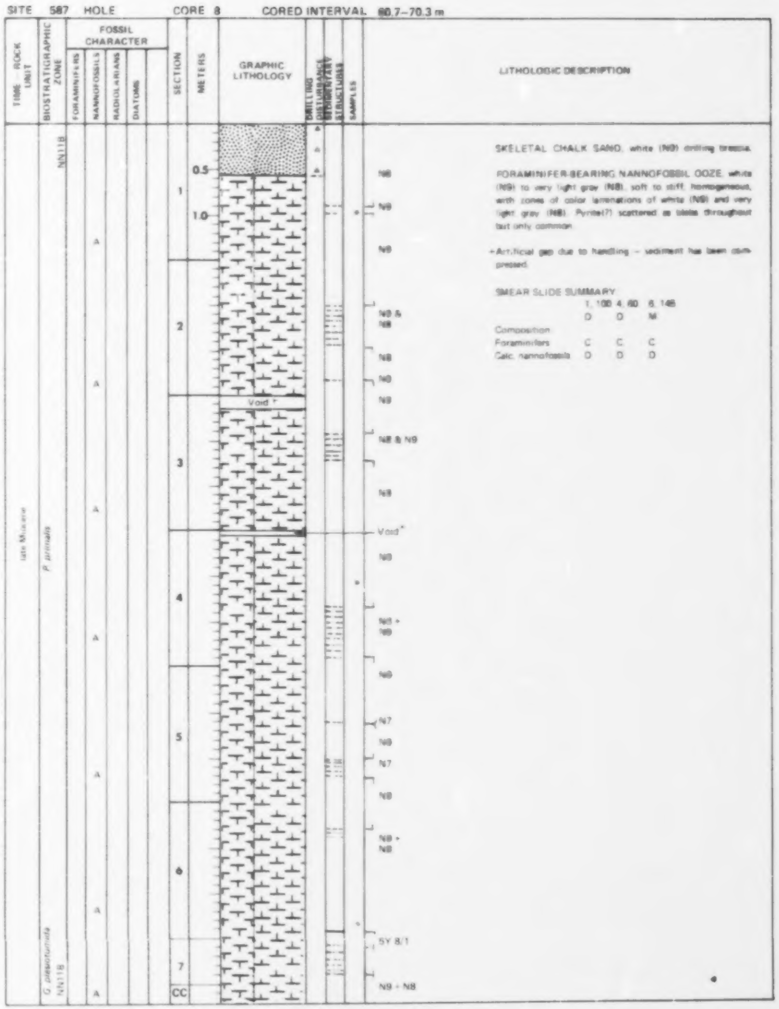
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to light greenish gray (5G 9/1) in top of Section 2 back to white (N9), soft, homogeneous but with faint laminae and interbeds of light gray (N7) color of same lithology. Some faint burrowing in Sections 2 and 4. Streaks of pyrite(?) common.

* Artificial gap due to core handling – sediment compressed.

SMEAR SLIDE SUMMARY

	1, 66	2, 25	4, 61	6, 70
	D	D	M	M
Composition:				
Pyrite	–	–	T	R
Carbonate unspec.	A	–	–	–
Foraminifers	C	C	C	C
Calc. nannofossils	D	A	A	D

SITE 587 HOLE CORE 8 CORED INTERVAL 60.7–70.3 m


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
P. primalis
G. plesiotumida
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void*
N8
N9
N9 & N8
N8 & N9
N8 + N9
N7
5Y 8/1
N9 + N8

LITHOLOGIC DESCRIPTION

SKELETAL CHALK SAND, white (N9) drilling breccia.

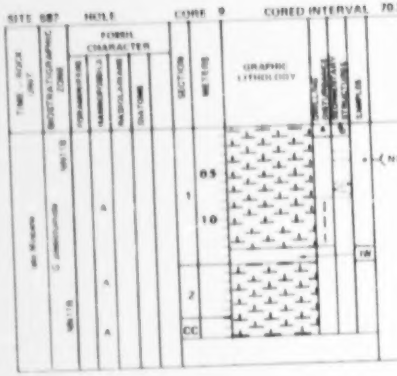
FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft to stiff, homogeneous, with zones of color laminations of white (N9) and very light gray (N8). Pyrite(?) scattered as blebs throughout but only common.

+ Artificial gap due to handling – sediment has been compressed.

SMEAR SLIDE SUMMARY

	1, 100	4, 60	6, 146
	D	D	M
Composition:			
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 587 HOLE CORE 9 CORED INTERVAL 70.3–79.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
G. conomiozea
NN11B
A
A
A
1
2
CC
0.5
1.0
N7
IW

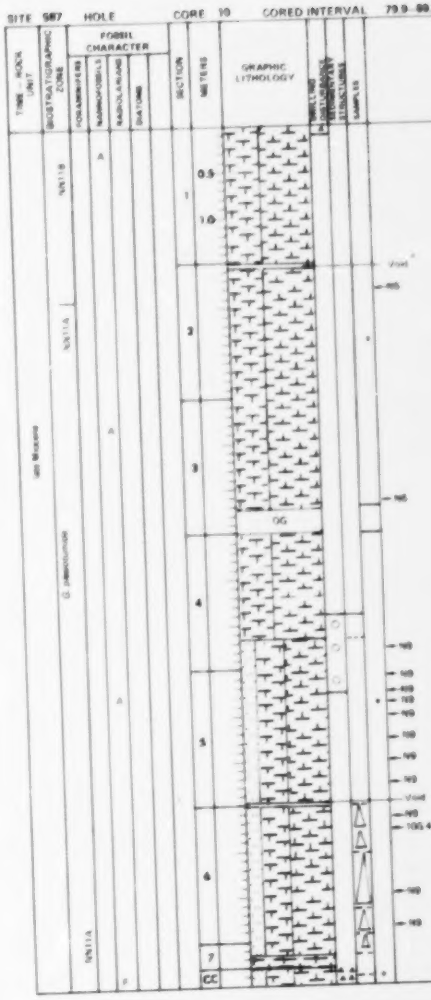
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, bluish white (5B 9/1), stiff, color laminations and swirls of very light gray (N8). Pyrite(?) concentration at Section 2, 2 to 3 cm.

SMEAR SLIDE SUMMARY

	1, 50	2, 2
	D	M
Texture		
Clay	D	
Composition		
Pyrite	–	C
Foraminifers	R	R
Calc. nannofossils	D	D
Sponge spicules	–	T
Other	T	–

SITE 587 HOLE CORE 10 CORED INTERVAL 79.9–89.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
NN11A
G. conomiozea
NN11A
A
A
A
F
1
2
3
4
5
6
7
CC
0.5
1.0
OG
Void*
N9
N9
N9
N9
N9
N9
N9
N9
N9
Void
N9
10G 4/2
N9
N9

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9), stiff, massive with rare very light gray (N8) diffuse laminae.

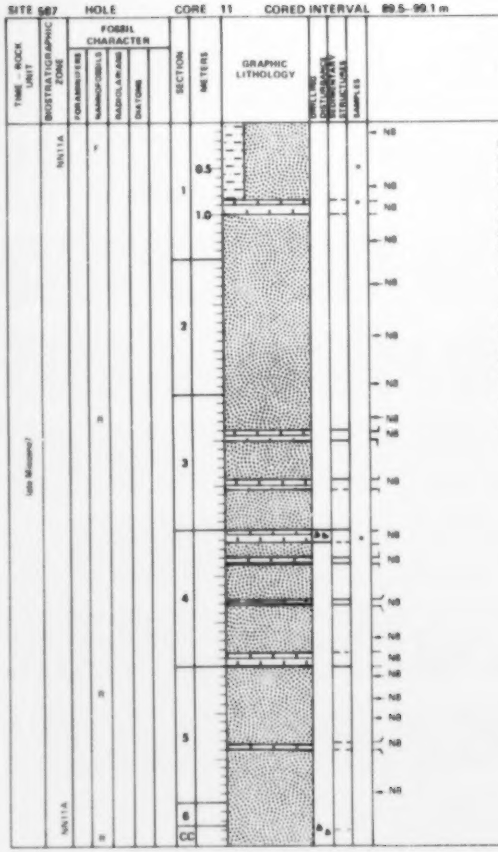
FORAMINIFER-BEARING SILTY SKELETAL NANNOFOSSIL OOZE, yellowish gray (5Y 8/1), soft, massive but with chunks and disrupted laminae of white (N9) ooze, possible normally graded beds in Section 6 and intermixed skeletal sandy gravel in Core Catcher.

SMEAR SLIDE SUMMARY

	2, 75	6, 10	CC, 6
	D	D	M
Texture			
Sand	–	C	–
Silt	C	A	C
Clay	D	A	D
Composition			
Carbonate unspec.	–	A	D
Foraminifers	C	C	C
Calc. nannofossils	D	A	C

* Artificial gap due to core handling.

SITE 587 HOLE CORE 11 CORED INTERVAL 89.5–99.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene?
NN11A
F
R
0.5
1.0
1
2
3
4
5
6
CC
NB

LITHOLOGIC DESCRIPTION

SKELETAL MUDDY FINE SAND, yellowish gray (5Y 8/1), soft, massive to subtly normally graded, includes rare chunks of very light gray (N8) nannofossil-bearing ooze or chalk.

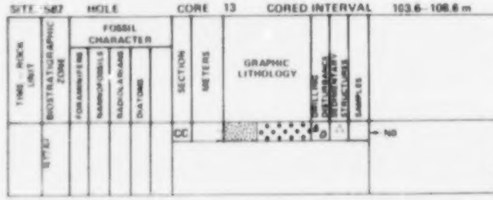
NANNOFOSSIL-BEARING SKELETAL OOZE OR CHALK, very light gray (N8), soft to more commonly hard, crudely laminated to chunky, interbedded with above skeletal sands.

SMEAR SLIDE SUMMARY

	1, 60 D	4, 10 D	1, 100 M
Texture:			
Sand	A	–	–
Silt	A	–	–
Clay	A	D	D
Composition:			
Carbonate unspec.	D	D	D
Foraminifers	C	–	–
Calc. nannofossils	C	C	C

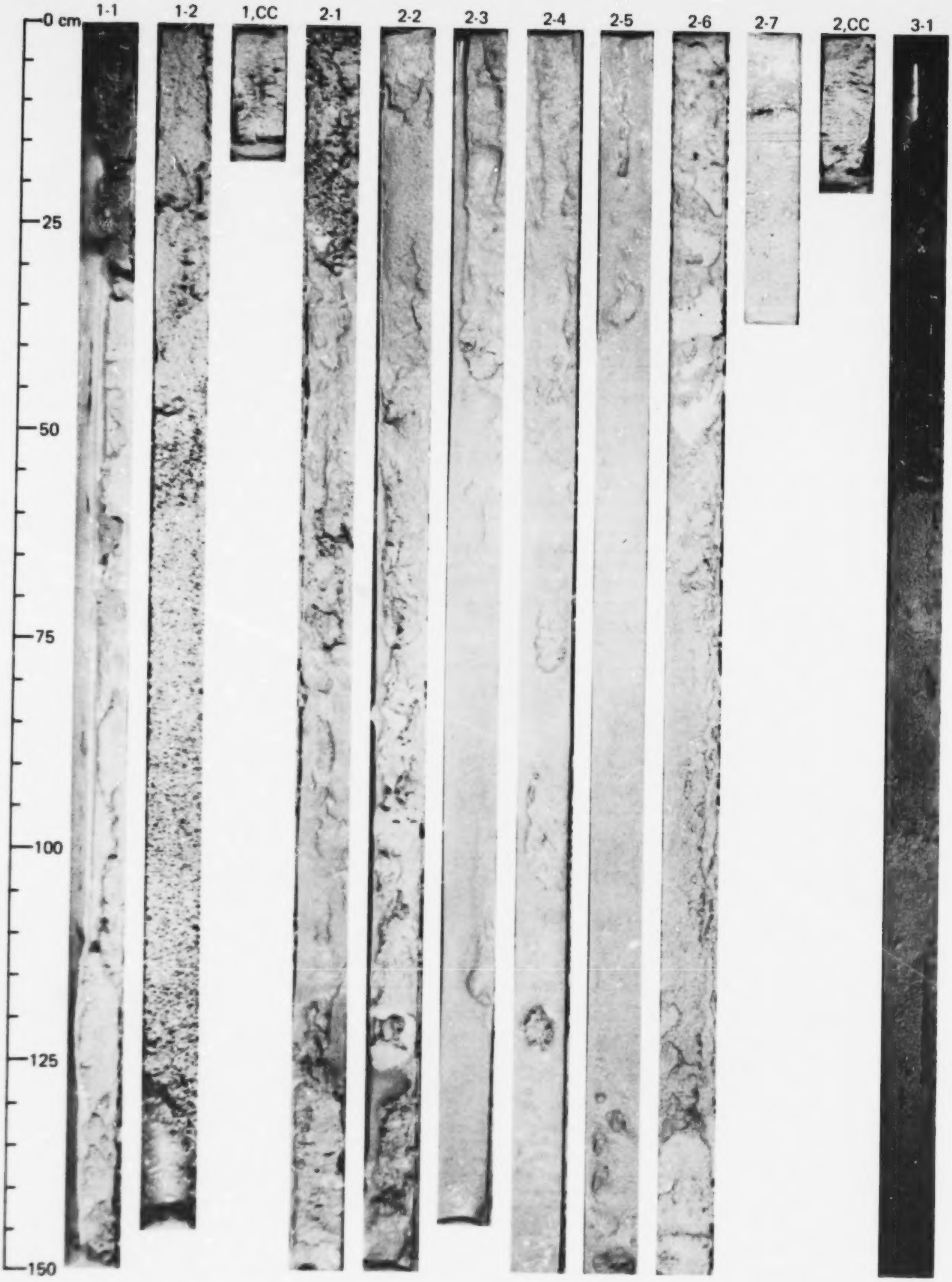
Core 12, 99.1–103.6 m: no recovery.

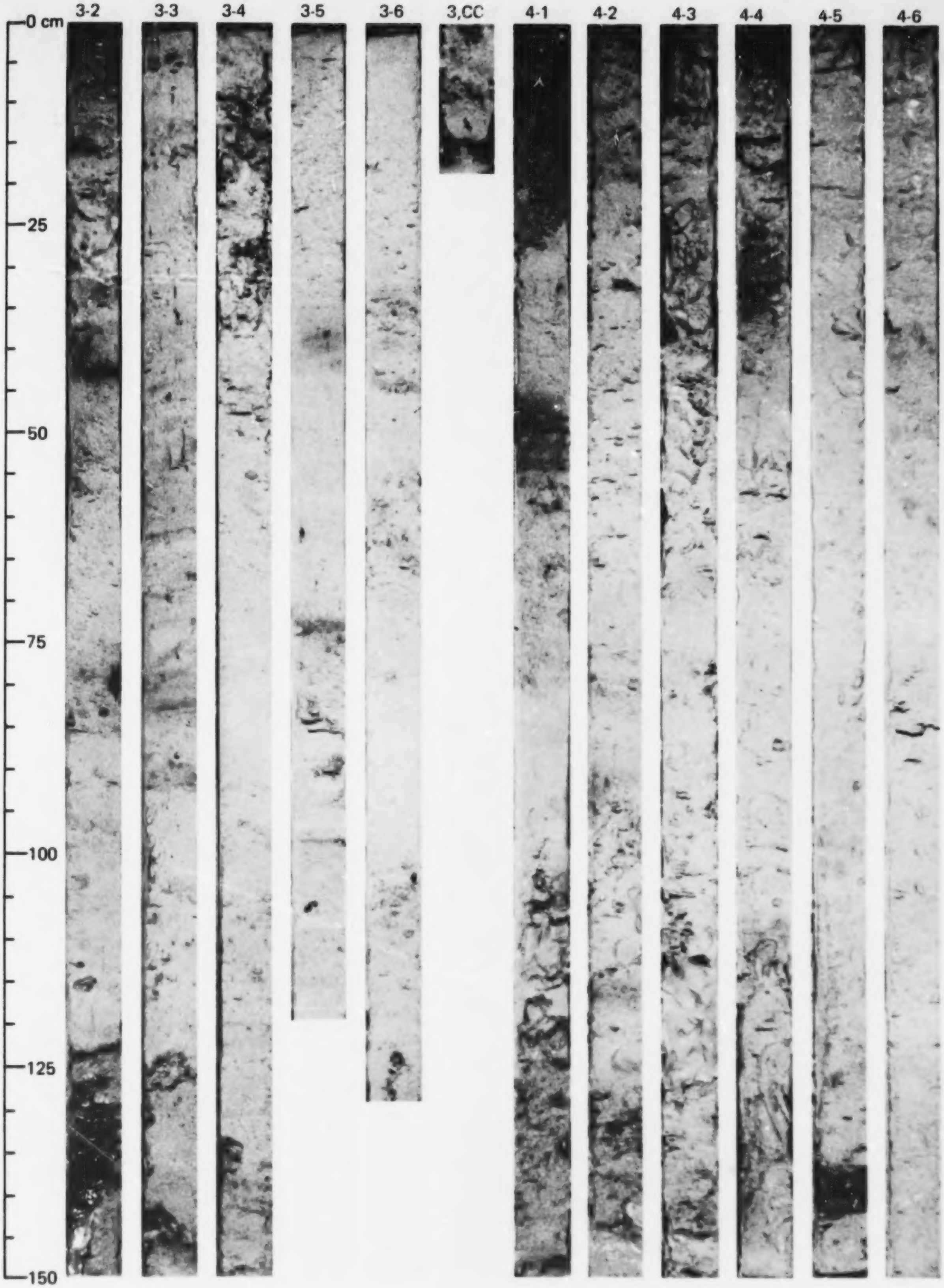
SITE 587 HOLE CORE 13 CORED INTERVAL 103.6–108.6 m

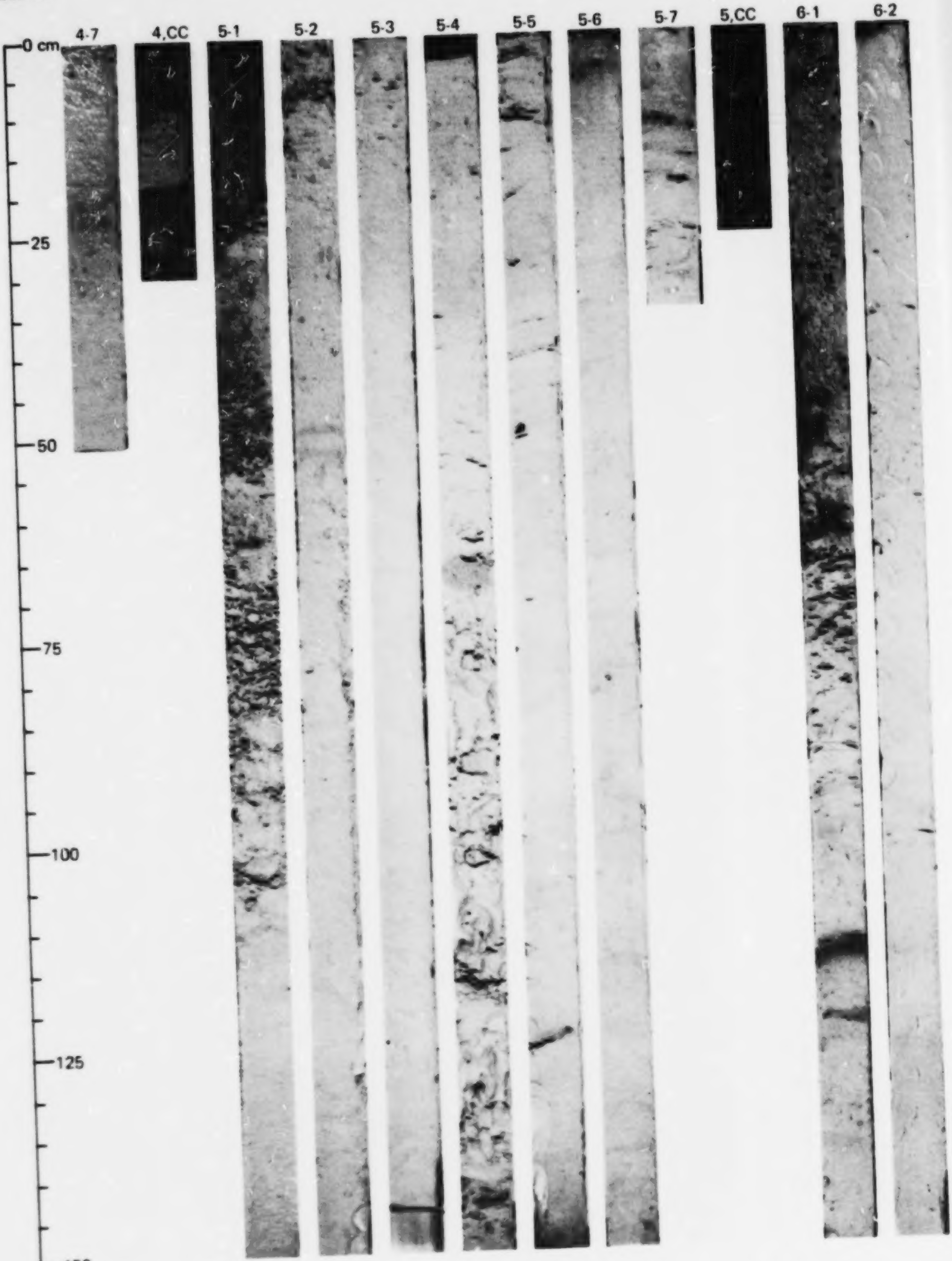

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
CC
NB

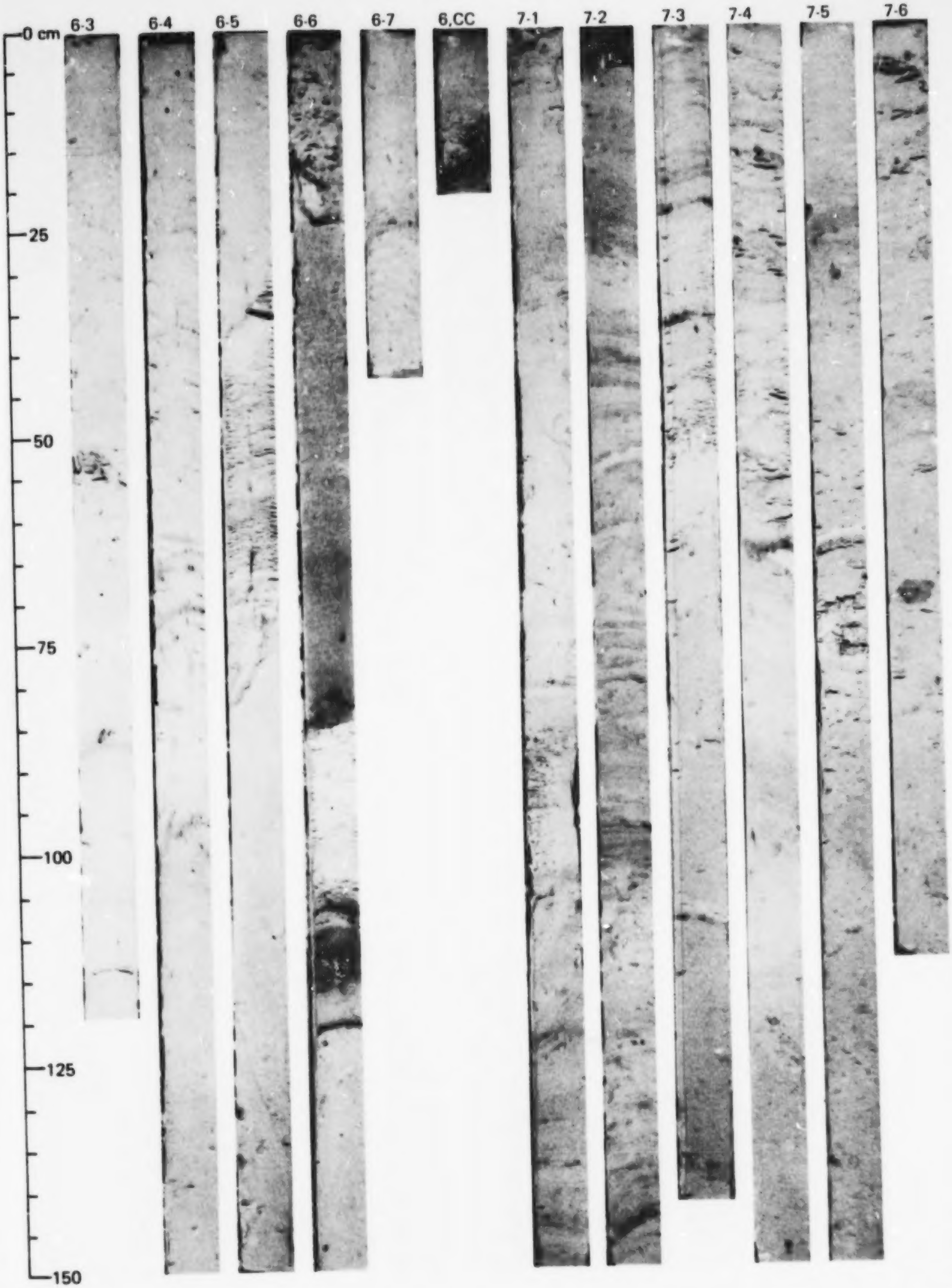
LITHOLOGIC DESCRIPTION

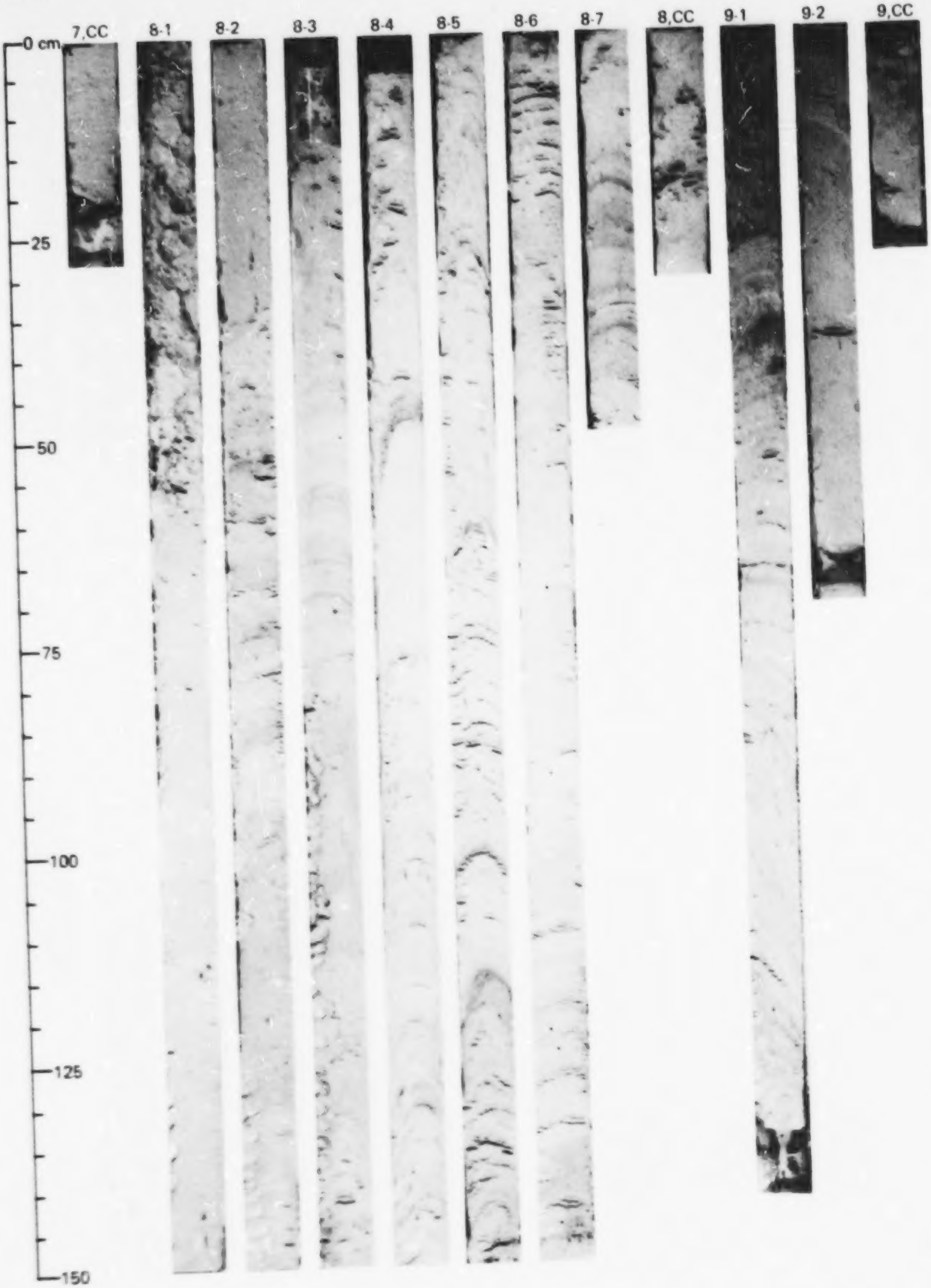
SKELETAL SANDY GRAVEL, yellowish gray (5Y 8/1), soft, normally graded (possibly due to core disturbance). Core Catcher sample only.

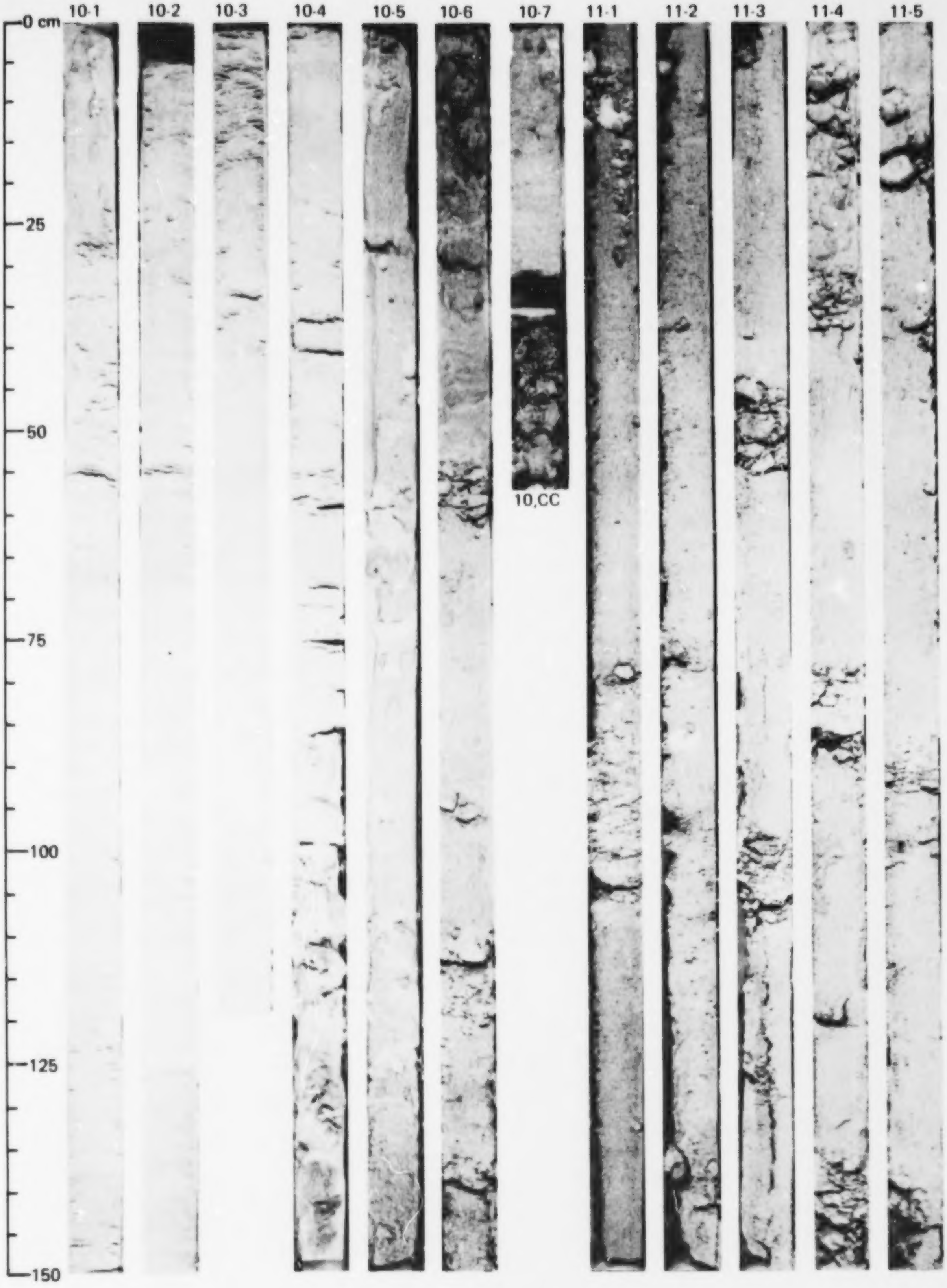

1-1
1-2
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2,CC
3-1
0 cm
25
50
75
100
125
150

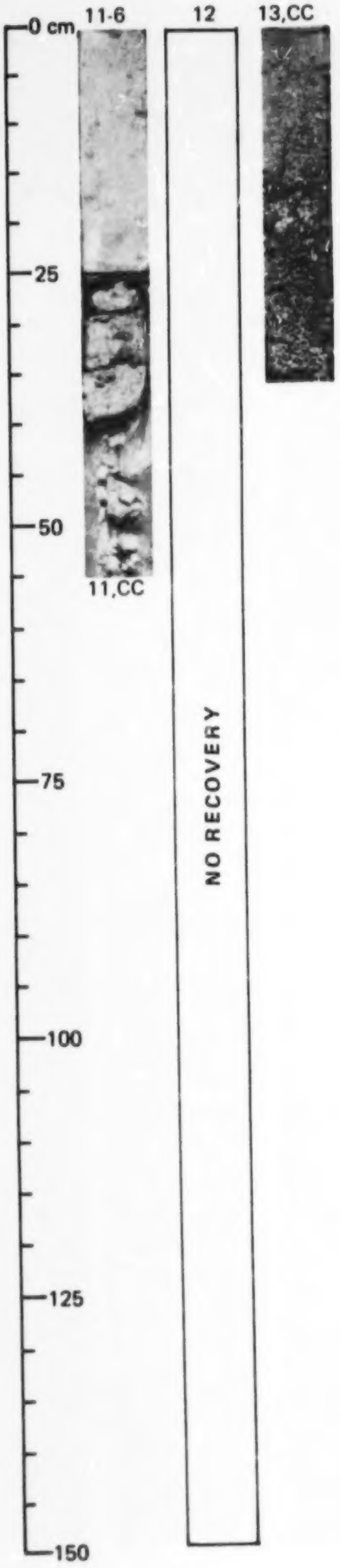

0 cm
25
50
75
100
125
150
3-2
3-3
3-4
3-5
3-6
3,CC
4-1
4-2
4-3
4-4
4-5
4-6


4-7
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5,CC
6-1
6-2
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4
7-5
7-6


7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8-7
8,CC
9-1
9-2
9,CC
0 cm
25
50
75
100
125
150


10-1
10-2
10-3
10-4
10-5
10-6
10-7
11-1
11-2
11-3
11-4
11-5
0 cm
25
50
75
100
125
150
10,CC


0 cm
25
50
75
100
125
150
11-6
11,CC
12
NO RECOVERY
13,CC

4. SITE 588: LORD HOWE RISE, 26°S[1]

Shipboard Scientific Party[2]

HOLE 588

Date occupied: 6 December 1982

Date departed: 8 December 1982

Time on hole: 30 hr.

Position: 26°06.7′S; 161°13.6′E

Water depth (sea level; corrected m, echo-sounding): 1533

Water depth (rig floor; corrected m, echo-sounding): 1543

Bottom felt (m, drill pipe): 1548

Penetration (m): 236.00

Number of cores: 26

Total length of cored section (m): 236.00

Total core recovered (m): 220.76

Core recovery (%): 93.5

Oldest sediment cored:
Depth sub-bottom (m): 236.00
Nature: Foraminifer–nannofossil ooze
Age: middle Miocene
Measured velocity (km/s): 1.617 km/s at 233 m

Basement: Not reached

HOLE 588A

Date occupied: 8 December 1982

Date departed: 8 December 1982

Time on hole: 20 hr.

Position: 26°06.7′S; 161°13.6′E

Water depth (sea level; corrected m, echo-sounding): 1533

Water depth (rig floor; corrected m, echo-sounding): 1543

Bottom felt (m, drill pipe): 1548

Penetration (m): 344.4

Number of cores: 18

Total length of cored section (m): 108.40

Total core recovered (m): 75.30

Core recovery (%): 69.4

Oldest sediment cored:
Depth sub-bottom (m): 344.4
Nature: Foraminifer–nannofossil ooze
Age: early Miocene

Basement: Not reached

HOLE 588B

Date occupied: 8 December 1982

Date departed: 10 December 1982

Time on hole: 31 hr.

Position: 26°06.7′S; 161°13.6′E

Water depth (sea level; corrected m, echo-sounding): 1533

Water depth (rig floor; corrected m, echo-sounding): 1543

Bottom felt (m, drill pipe): 1548

Penetration (m): 277.4

Number of cores: 31

Total length of cored section (m): 277.40

Total core recovered (m): 255.87

Core recovery (%): 93

Oldest sediment cored:
Depth sub-bottom (m): 277.4
Nature: Foraminifer–nannofossil ooze
Age: middle Miocene

Basement: Not reached

HOLE 588C

Date occupied: 10 December 1982

Date departed: 11 December 1982

Time on hole: 12 hr.

Position: 26°06.7′S; 161°13.6′E

Water depth (sea level; corrected m, echo-sounding): 1533

Water depth (rig floor; corrected m, echo-sounding): 1543

Bottom felt (m, drill pipe): 1548

Penetration (m): 488.1

Number of cores: 19

Total length of cored section (m): 182.40

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

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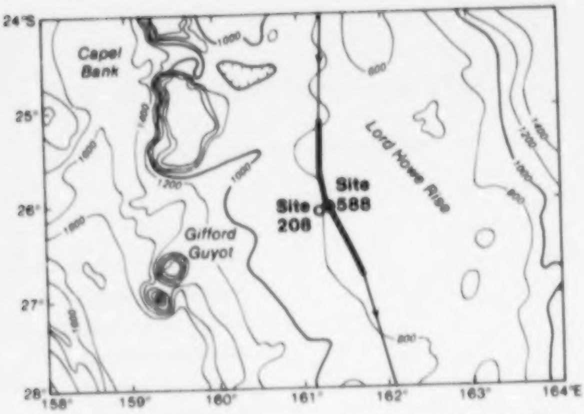

Figure 1. Regional bathymetry (fathoms) around Site 588, after Mammerickx, et al., 1974. *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Figure 2.

Total core recovered (m): 135.61

Core recovery (%): 74.3

Oldest sediment cored:
Depth sub-bottom (m): 488.1
Nature: Siliceous foraminifer-bearing nannofossil chalk and foraminifer-bearing chert
Age: middle Miocene

Basement: Not reached

Principal results: Site 588 consists of four holes: Hole 588, which was cored continuously with the HPC from 0 to 236.0 m sub-bottom; Hole 588A, cored continuously with the HPC from 236.0 to 344.4 m; Hole 588B, cored continuously with the HPC from 0 to 277.4 m; and Hole 588C, cored continuously with the rotary drill from 305.7 to 488.1 m BSF.

Site 588 is located at DSDP Site 208, in the warm subtropical water mass at 26°S.

The HPC sequence through carbonate sediments is a record penetration of 315 m, extending from the Quaternary to sediments of late early Miocene age (17 m.y.; Zone NN3 and *Globorotalia miozea* Zone). The overlapping hydraulic piston cores effectively provide 100% recovery of this sequence. Core quality is particularly good in the Miocene, much less so in the Pliocene, and especially poor in the Quaternary, which is soupy. The carbonate fossil sequence is exquisite through the Neogene, but less so in Oligocene sediments. Foraminiferal and calcareous nannofossil zonal sequences are complete, suggesting that there are no hiatuses above the upper Oligocene (NP24). A paleomagnetic polarity stratigraphy has been identified down to the upper part of the Gilbert Chron (about 3.5 m.y.).

Two sedimentary units are distinguished, the upper one divided into three subunits. Subunit IA is a brownish, foraminifer-rich nannofossil ooze in an oxidized and winnowed environment. Subunit IB, comprising most of the sediment column, is a foraminifer-bearing nannofossil ooze. Subunit IC is chalk. There are many thin volcanic ash layers throughout the Miocene sequence; they occur as singlets, doublets, or triplets and exhibit quasi-regular perodicities in some intervals. Most are completely undisturbed by bioturbation, which is unusually limited in this site. Unit II is a light greenish gray, siliceous foraminifer-bearing nannofossil chalk and associated chert of Eocene age.

Iron sulfides are persistent throughout the section and have a close association with volcanic ash layers. The site terminated in middle Eocene silica-rich chalks and cherts.

Textbook examples of microfaults and slickensides occur in three upper lower Miocene cores in a zone where ooze grades downward into chalks. Surfaces are occasionally mineralized by iron sulfide and possibly rhodochrosite.

The uncorrected rate of sedimentation is as follows: early Oligocene–early Miocene, 20.6 m/m.y.; early Miocene, 14.4; middle Miocene–early Pliocene, 17.4; lower Pliocene, 29.5; Quaternary, 12.2.

BACKGROUND AND OBJECTIVES

Site 588 (Fig. 1) was drilled at the same location as Site 208 on the northern part of Lord Howe Rise (26°06′S; 161°13′E) to obtain a high-quality, continuously cored sequence through the upper Paleogene and Neogene. The chosen site overlies a relatively thick sequence of acoustically transparent sediments (Figs. 2 and 3). Previous investigations have demonstrated that the planktonic foraminiferal assemblages at this latitude are made up of both tropical and temperate elements. Site 588 is now located in the warm subtropical water mass which lies between the true tropical water masses to the north and transitional water masses to the south. However, Site 588 experienced 5–10° of northernly movement during the Neogene in association with movements of the Indian Plate (Sclater et al., in press). During the early Miocene, Site 588 was located at about 36°S in the present-day temperate area and within the zone of westerly winds. This northward movement from higher to lower latitudes must have had a major effect upon the ancient biogeography of the planktonic microfossil assemblages.

The section at Site 208 consists of about 430 m of Neogene and 58 m of upper Oligocene foraminiferal–nannofossil oozes which make up Unit 1 as defined by the Leg 21 sedimentologists. Unit 1 is underlain by Unit 2, which is made up of Upper Cretaceous to lower middle Eocene siliceous-fossil-bearing nannofossil chalk. Unit 1 is separated from Unit 2 by the regional unconformity. The Site 208 sequence was continuously rotary cored from the Quaternary to the uppermost Miocene, then discontinuously cored to the base of the sequence. Rotary coring produced the usual mechanical disturbance of sediments; in addition, there are many long coring gaps in the section at Site 208.

The plan for Site 588 was to core two separate holes using the HPC in the upper part of the sequence, followed by continuous rotary coring in one hole to the level immediately below the regional unconformity separating the middle Eocene from the upper Oligocene at 488 m sub-bottom depth. Such a sequence would include all of Unit 1 as defined by the Leg 21 shipboard party.

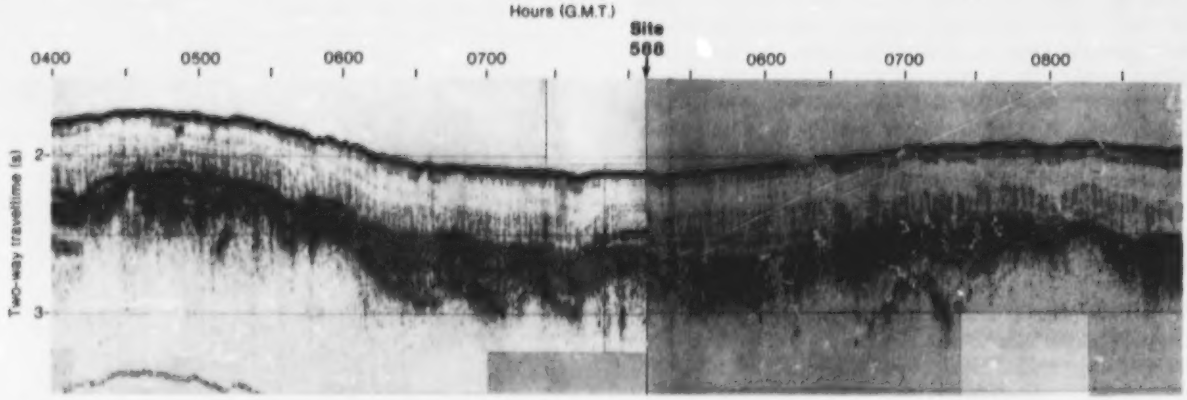

Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 588; bandpass filter 40–160 Hz.

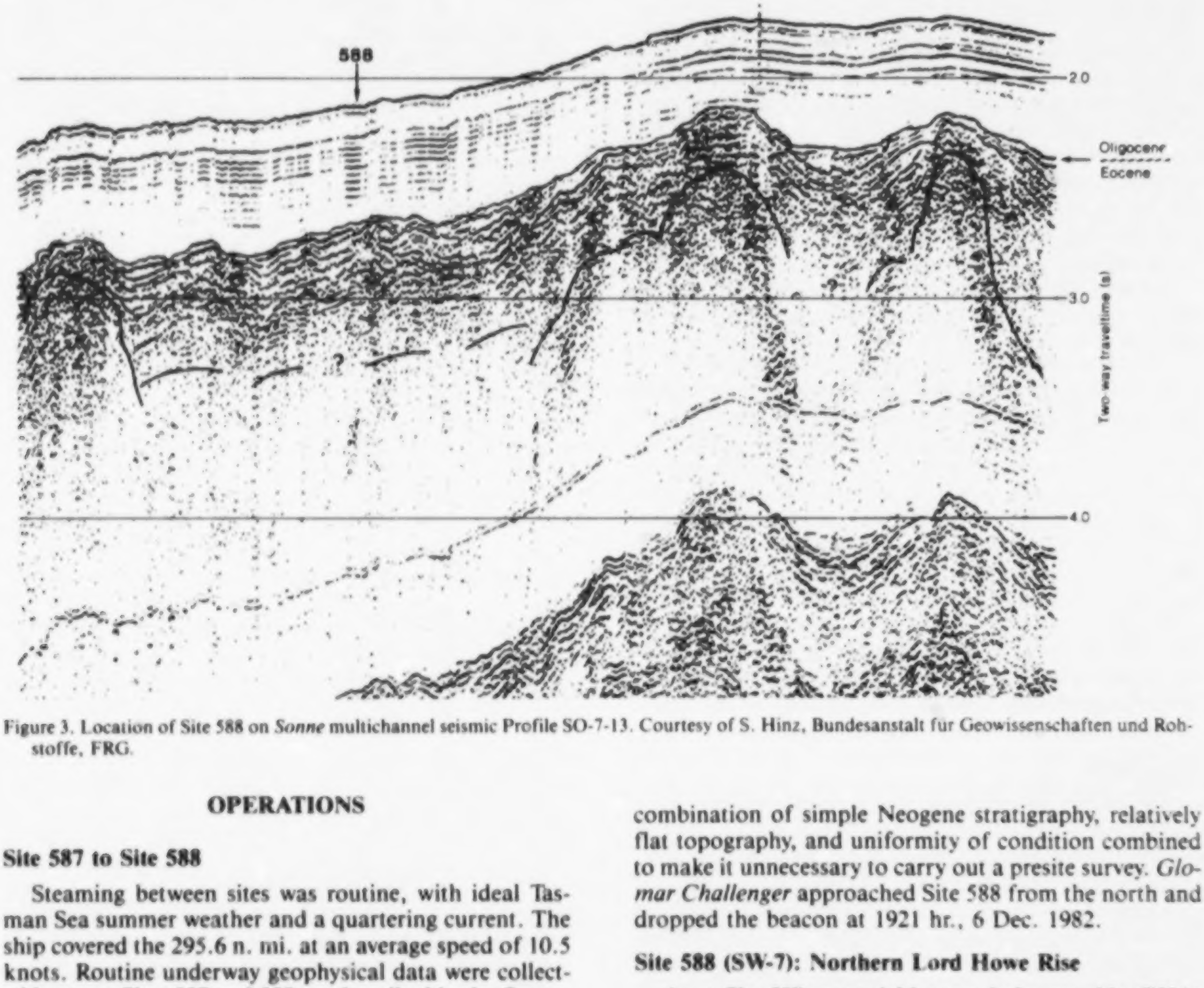

Figure 3. Location of Site 588 on *Sonne* multichannel seismic Profile SO-7-13. Courtesy of S. Hinz, Bundesanstalt für Geowissenschaften und Rohstoffe, FRG.

OPERATIONS

Site 587 to Site 588

Steaming between sites was routine, with ideal Tasman Sea summer weather and a quartering current. The ship covered the 295.6 n. mi. at an average speed of 10.5 knots. Routine underway geophysical data were collected between Sites 587 and 588, as described in the Operations Chapter for Site 587.

Site 588 was designed to reoccupy and utilize the HPC at Site 208, drilled during DSDP Leg 21. Several excellent seismic profiles were available for site selection (*Conrad* 12; *Glomar Challenger*, Leg 21; *Sonne* 50-7-12). The combination of simple Neogene stratigraphy, relatively flat topography, and uniformity of condition combined to make it unnecessary to carry out a presite survey. *Glomar Challenger* approached Site 588 from the north and dropped the beacon at 1921 hr., 6 Dec. 1982.

Site 588 (SW-7): Northern Lord Howe Rise

As at Site 587, a special bottom-hole assembly (BHA) was run, compatible with both piston coring and extended core barrel (XCB) rotary coring. The operational plan for Site 588 called for taking duplicate unbroken piston-cored sequences through the Neogene, followed by rotary coring to the base of the Miocene.

The first variable-length (VL) HPC shot was taken with the bit at 1544 m; it recovered a 5.65-m core which established the mud line at 1548 m (Table 1). Piston coring continued easily through calcareous ooze ranging from soupy to stiff for the first 216.8 m. Recovery was consistently nearly 100%, except for Core 588-8, which came up empty. During this interval, 23 9.5-m VLHPC cores were taken. Full stroke on all was achieved using only two shear pins. Cores 588-24 and 588-25 were shot using three shear pins. Overpulls to free the tool after shoot-off slowly increased to a maximum of 20,000 lbs.[3]

At Core 588-26, somewhat more than 100,000 lbs. overpull was applied to free the tool before the driller could stop the draw-works. The piston corer was recovered with its lower core-containing section missing, because the excessive tensile load associated with the overpull had caused a mechanical failure. The hole had to be terminated at this point.

Hole 588A

The bit was pulled to the mud line and Hole 588A was spudded at 0025 hr., 8 December, and washed to the termination point of Hole 588—236.0 BSF. One more 9.5-m VLHPC was deployed. When it experienced full stroke followed by excessive overpull, the bit was washed down over the entire 9.5 m until the tool was washed free.

It was then decided to employ the 5-m VLHPC as far as possible. Overpull was taken to a limit of 20-30,000 lbs. on each core. If the corer could not be freed by pulling at that limit, the bit was washed over the extended section.

A new record depth for piston coring was reached in this manner—315.6 m BSF—and the oldest sediments ever successfully piston cored were recovered (upper lower Miocene). However, as the sediments stiffened, it became impossible to wash the bit over the protruding inner barrel without gouging the extended tool. Therefore, VLHPC work was terminated at Core 588A-15. Surprisingly, full stroking continued throughout the piston-cored sequence, despite the record total depth of penetration.

The XCB was then deployed for Cores 588A-16 to -18. Poor recovery coupled with other symptoms indicated that the XCB was not functioning correctly, and it was decided to terminate Hole 588A and perform the repeat piston core sequence, using the time to modify the XCB system.

Hole 588B

Once again the bit was pulled to the mud line to spud a new hole. The vessel was offset 100 ft. to the north to assure a clean seafloor for a mud line core and Hole 588B was spudded at 2210 hr., 8 December. A good mud line core was shot from 1546 m to be certain that the coring sequence was staggered with respect to Holes 588 and 588A.

Piston coring proceeded smoothly again through calcareous ooze with scattered ash layers. Again full stroke of the 9.5 m VLHPC was routinely achieved with two

Table 1. Coring summary, Site 588.

Core No.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 588							
1	7	0200	1548.0-1553.6	0.0-5.6	5.6	5.65	100
2	7	0250	1553.6-1563.2	5.6-15.2	9.6	9.64	100
3	7	0340	1563.2-1572.8	15.2-24.8	9.6	9.18	95.6
4	7	0420	1572.8-1582.4	24.8-34.4	9.6	9.43	98.2
5	7	0510	1482.4-1592.0	34.4-44.0	9.6	9.11	94.9
6	7	0600	1592.0-1601.6	44.0-53.6	9.6	9.38	97.7
7	7	0650	1601.6-1611.2	53.6-63.2	9.6	9.05	94.2
8	7	0730	1611.2-1620.8	63.2-72.8	9.6	0.0	0.0
9	7	0820	1620.8-1630.4	72.8-82.4	9.6	9.48	98.7
10	7	0910	1630.4-1640.0	82.4-92.0	9.6	8.78	91.4
11	7	1000	1640.0-1649.6	92.0-101.6	9.6	9.49	98.8
12	7	1050	1649.6-1659.2	101.6-111.2	9.6	9.54	99.4
13	7	1130	1659.2-1668.8	111.2-120.8	9.6	9.49	98.5
14	7	1220	1668.8-1678.4	120.8-130.4	9.6	9.71	100
15	7	1320	1678.4-1688.0	130.4-140.0	9.6	9.44	98
16	7	1415	1688.0-1697.6	140.0-149.6	9.6	5.8	61
17	7	1510	1697.6-1707.2	149.6-159.2	9.6	9.63	100
18	7	1555	1707.2-1716.8	159.2-168.8	9.6	9.38	98
19	7	1630	1716.8-1726.4	168.8-178.4	9.6	9.64	100+
20	7	1735	1726.4-1736.0	178.4-188.0	9.6	9.77	100+
21	7	1820	1736.0-1745.6	188.0-197.6	9.6	9.78	100+
22	7	1930	1745.6-1755.2	197.6-207.2	9.6	9.81	100+
23	7	2015	1755.2-1764.8	207.2-216.8	9.6	9.82	100+
24	7	2100	1764.8-1774.4	216.8-226.4	9.6	9.66	100+
25	7	2140	1774.4-1785.0 (tool left in hole)	226.4-236.0	9.6	10.04	100+
					236.00	220.76	93.5
Hole 588A							
1	8	0300	1784.0-1793.6	236.0-245.6	9.6	9.76	100+
2	8	0400	1793.6-1798.6	245.6-250.6	5.0	5.16	100+
3	8	0500	1798.6-1803.6	250.6-255.6	5.0	5.23	100+
4	8	0550	1803.6-1808.6	255.6-260.6	5.0	4.91	98.2
5	8	0645	1808.6-1813.6	260.6-265.6	5.0	4.39	100+
6	8	0740	1813.6-1818.6	265.6-270.6	5.0	5.18	100+
7	8	0830	1818.6-1823.6	270.6-275.6	5.0	5.19	100+
8	8	0920	1823.6-1828.6	275.6-280.6	5.0	5.27	100+
9	8	1010	1828.6-1833.6	280.6-285.6	5.0	4.96	99.2
10	8	1115	1833.6-1838.6	285.6-290.6	5.0	5.20	100+
11	8	1210	1838.6-1843.6	290.6-295.6	5.0	4.22	84.4
12	8	1308	1843.6-1848.6	295.6-300.6	5.0	5.19	100+
13	8	1415	1848.6-1853.6	300.6-305.6	5.0	5.21	100+
14	8	1500	1853.6-1858.6	305.6-310.6	5.0	3.78	76
15	8	1545	1858.6-1863.6	310.6-315.6	5.0	5.22	100+
16	8	1720	1863.6-1873.2	315.6-325.2	9.6	0.16	2
17	8	1850	1873.2-1882.8	325.2-334.8	9.6	2.35	24
18	8	1930	1882.8-1892.4	334.8-344.4	9.6	2.89	30
					108.40	84.27	77.7
Hole 588B							
1	8	2250	1547.8-1555.6	0.0-7.8	7.8	7.79	100
2	8	2350	1555.6-1565.2	7.8-17.4	9.6	9.63	100+
3	9	0025	1565.2-1574.8	17.4-27.0	9.6	9.57	99.6
4	9	0120	1574.8-1584.4	27.0-36.6	9.6	8.91	92.8
5	9	0200	1584.4-1594.0	36.6-46.2	9.6	9.70	100+
6	9	0305	1594.0-1603.6	46.2-55.8	9.6	7.92	82.5
7	9	0345	1603.6-1613.2	55.8-65.4	9.6	9.17	95.5
8	9	0430	1613.2-1622.8	65.4-75.0	9.6	9.58	100
9	9	0520	1622.8-1632.4	75.0-84.6	9.6	9.58	99.7
10	9	0600	1632.4-1642.0	84.6-94.2	9.6	4.04	42.0
11	9	0648	1642.0-1651.6	94.2-103.8	9.6	9.49	98.8
12	9	0740	1651.6-1661.2	103.8-113.4	9.6	9.83	100+
13	9	0830	1661.2-1670.8	113.4-123.0	9.6	9.42	98.1
14	9	0920	1670.8-1680.4	123.0-132.6	9.6	9.69	100+
15	9	1000	1680.4-1690.0	132.6-142.2	9.6	9.30	96.8
16	9	1053	1690.0-1699.6	142.2-151.8	9.6	9.14	95.2
17	9	1310	1699.6-1709.2	151.8-161.4	9.6	9.68	100+
18	9	1400	1709.2-1718.8	161.4-171.0	9.6	9.45	98
19	9	1450	1718.8-1728.4	171.0-180.6	9.6	9.60	100
20	9	1545	1728.4-1738.0	180.6-190.2	9.6	9.80	100+
21	9	1630	1738.6-1747.6	190.2-199.8	9.6	9.47	99
22	9	1725	1747.6-1757.2	199.8-209.4	9.6	9.30	97
23	9	1815	1757.2-1766.8	209.4-219.0	9.6	9.66	100+
24	9	1925	1766.8-1776.4	219.0-228.6	9.6	8.91	93
25	9	2015	1776.4-1781.4	228.6-233.6	5.0	5.15	100+
26	9	2104	1781.4-1786.4	233.6-238.6	5.0	5.27	100+
27	9	2205	1786.4-1791.4	238.6-243.6	5.0	5.15	100+
28	9	2300	1791.4-1796.4	243.6-248.6	5.0	5.20	100+
29	10	0145	1796.4-1806.0	248.6-258.2	9.6	6.95	72.3
30	10	0250	1806.0-1815.6	258.2-267.8	9.6	3.79	39.4
31	10	0415	1815.6-1825.2	267.8-277.4	9.6	5.73	59.6
					277.40	255.87	93.0
Hole 588C							
1	10	1630	1853.5-1863.1	305.7-315.3	9.6	9.42	98
2	10	1735	1863.1-1872.1	315.3-324.9	9.6	8.99	94
3	10	1830	1872.7-1882.3	324.9-334.5	9.6	8.94	93

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[3] The overpull is a measure of the force required to overcome the adhesion and suction which the sediment exerts on the extended section of the piston corer when it is implanted.

Table 1. (Continued).

Core No.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top–Bottom	Depth below seafloor (m) Top–Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 588C (Cont.)							
4	10	1925	1882.3-1891.9	334.5-344.1	9.6	8.82	92
5	10	2025	1891.9-1901.5	344.1-353.7	9.6	9.02	94
6	10	2130	1901.5-1911.1	353.7-363.3	9.6	9.63	100 +
7	10	2210	1911.1-1920.7	363.3-372.9	9.6	5.88	61.2
8	10	2325	1920.7-1930.3	373.9-382.5	9.6	9.43	98.2
9	11	0002	1930.3-1939.9	382.5-392.1	9.6	9.62	100 +
10	11	0052	1939.9-1949.5	392.1-401.7	9.6	7.42	80.6
11	11	0245	1949.5-1959.1	401.7-411.3	9.6	4.44	46.2
12	11	0355	1959.1-1968.7	411.3-420.9	9.6	8.13	84.6
13	11	0455	1968.7-1978.3	420.9-430.5	9.6	8.88	92.5
14	11	0550	1978.3-1987.9	430.5-440.1	9.6	7.20	75.0
15	11	0640	1987.9-1997.5	440.1-449.7	9.6	6.40	66.6
16	11	0743	1997.5-2007.1	449.7-459.3	9.6	5.32	55.4
17	11	0835	2007.1-2016.7	459.3-468.9	9.6	5.60	58.3
18	11	0950	2016.7-2026.3	468.9-478.5	9.6	0.62	6.4
19	11	1040	2026.3-2035.9	478.5-488.1	9.6	0.85	8.85
					182.40	134.61	73.8

shear pins. The same scenario of increasing overpull requirements was experienced as in the previous hole, this time beginning about 30 m higher. Cores 588B-25 to 588B-28 were taken with the 5-m VLPHC. Piston coring was then terminated.

Again the XCB was deployed, now modified to allow proper venting. Cores were taken on all three deployments but they were not of good quality. Partial collapse and splitting of the plastic core liners occurred on all three attempts. The XCB obviously needed further work and the scientific objective of rotary coring to the Neogene/Paleogene unconformity had not yet been reached, so it was decided to trip the pipe in order to change the bit and BHA for conventional rotary coring.

Hole 588C

The pipe was tripped and a standard BHA with a long-tooth, tungsten carbide insert F93CK bit was assembled and run back to the seafloor. Hole 588C was spudded at 1307 hr., 10 December. The bit was quickly washed to a depth of 305.7 m BSF to provide a slight overlap with the deepest penetration of the piston coring done earlier.

Routine rotary coring then followed, with good core recovery through foraminifer-bearing nannofossil chalk with green ash layers and abundant burrows. The only delay was a 45 min. wait on weather while the vessel took a 400 ft. excursion under the influence of a brief but dramatic line squall bearing 50 m.p.h. winds. At 488.1 m BSF the scientific objective was reached and the hole was terminated. The pipe was tripped and the vessel got under way for Site 589 at 1536 hr., 11 December.

LITHOSTRATIGRAPHY

Site 588 consists of four holes: Hole 588 was cored continuously with the HPC from 0 to 236.0 sub-bottom; Hole 588A was cored continuously with the HPC from 236.0 to 344.4 m; Hole 588B was cored continuously with the HPC from 0 to 277.4 m; and Hole 588C was cored continuously with the rotary drill from 305.7 to 488.1 m sub-bottom. The recovered sequence is divided into two lithostratigraphic units, based upon color and composition (Fig. 4; Table 2).

Subunit IA is a foraminifer-bearing nannofossil ooze to nannofossil-bearing foraminiferal ooze extending from the seafloor to 6.5 or 6.8 m BSF. It is distinguished by its color, which ranges from orange to brown, whereas that of the underlying Subunit IB is white to light gray. Within Subunit IA, a color gradation exists from grayish orange (10Y 7/4, 10Y 7/3) and pale yellowish brown (10Y 6/2) in the topmost meter of the sediment column to very pale orange (10Y 8/2) in the remainder of the subunit.

There are several distinct beds within Subunit IA that differ in color, grain size, and composition. The beds are generally separated from each other by sharp contacts. The foraminifers vary in abundance from 5 to 75% and usually form about 25% of the sediment (estimated from smear slides; see Fig. 5). High abundance (75%) was seen only in Sample 588B-1-4, 115-150 cm, which contains the coarsest sediment found at Site 588. Calcareous nannofossils comprise the bulk (25 to 95%) of the remaining sediment. Noncarbonate components in this subunit include traces of quartz, feldspar, heavy minerals, and sponge spicules.

The preliminary interpretation is that Subunit IA is an oxidized and winnowed facies. The sharp color contrast that separates Subunit IA from underlying Subunit IB represents a fundamental change in diagenetic environment as well as in sedimentological environment. Increased current caused winnowing and concentrated the foraminifers. As a result of the coarser grain size, oxidation of organic matter in these sediments was complete within 7 m of the seafloor.

Subunit IB comprises much of the sediment column at Site 588 (6.5 to about 250 m). It is predominantly a foraminifer-bearing nannofossil ooze; rarely, it is a foraminifer–nannofossil ooze or a nannofossil ooze. It is distinguished from underlying Subunit IC by its softness: Subunit IC is a chalk. Subunit IC grades from soft ooze at its top to firm ooze at about 150 to 180 m (Holes 588 and 588B, respectively) to chalk at about 215 to 260 m (Holes 588 and 588B, respectively). Foraminifer abundances typically vary between 5 and 25% in both subunits. Siliceous microfossils are almost entirely absent. The only noncarbonate components that occur in greater than trace amounts are volcanic ash and iron sulfide minerals. The changing abundance of these components is responsible for the overall color changes within Subunits IB and IC. The volcanic ash imparts a green color to the normally white sediment, in shades from very light greenish gray to dark bluish green. The iron sulfide imparts a gray color to the sediment, in shades varying from very light gray to dark gray. Because these components are generally less than 10% in abundance, the light colors prevail.

Sedimentary structures in Subunits IB and IC include bedding and burrowing features. Some beautiful examples of Zoophycos and Chondrites burrows occur throughout this unit, as do a number of circular or ovoid (0.5-3.0 cm across) burrow sections and mottles. Some flaser-

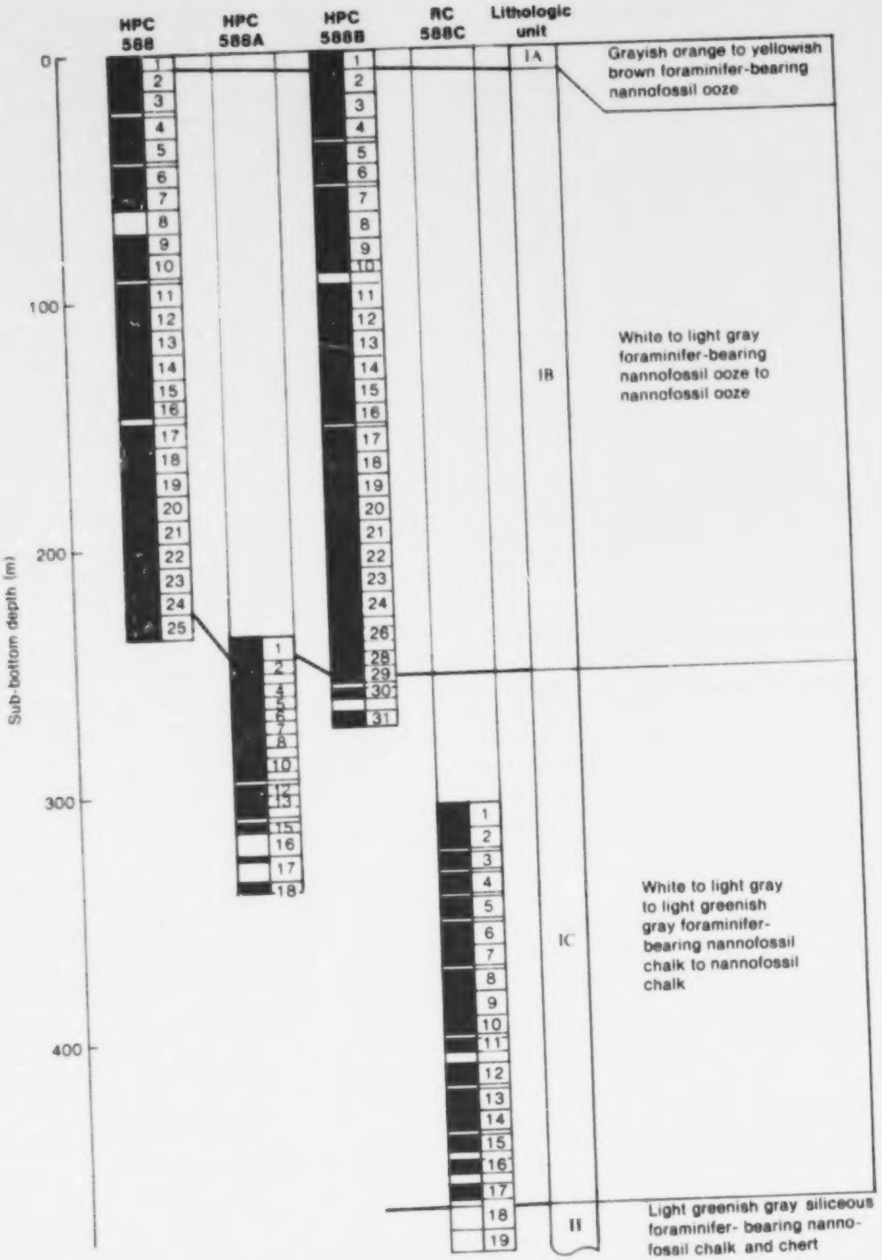

Figure 4. Lithostratigraphy of Site 588. Recovery in black. HPC = hydraulic piston cored, RC = rotary cored.

like bedding is apparent within Subunit IC (Sections 588C-5-3 and 588C-18-1).

Disseminated volcanic ash or glass is present throughout Subunits IB and IC. Glass occurs as ovoid bubbles and as angular shards in the uppermost parts of the unit (e.g., 588-4-1, 81 cm). In addition, thin (0.5–15 mm thick), light greenish gray laminae, possibly composed of altered volcanic ash, are common below about 160 m sub-bottom to the base of the unit. These layers almost exclusively occur in singlets, doublets, and triplets within about 2 cm of section. Furthermore, the layers occur throughout the section with quasi-regular frequency.

Iron sulfide minerals have been diagenetically formed throughout the unit as a result of mild degrees of microbial sulfate reduction. These minerals occur in blebs, pockets, and burrows. Small, solid tubes (1 to 2 mm in diameter, several cm long) of black iron sulfide fill many of the small burrows. One large (3 to 5 cm) pyrite nodule in Section 588-17-2 containing well-formed pyrite crystals is a burrow fill. A close stratigraphic association oc-

Table 2. Lithostratigraphy at Site 588.

Lithologic units	Cores[a]	Sub-bottom depth (m)	Description	Age
IA	1-2 1B	0.0-6.6 0.0-6.8	Grayish orange to yellowish brown (oxidized), foraminifer-bearing nannofossil ooze	Quaternary
IB	2-24 1A 1B-29B	6.6-226.4 236.0-245.6 6.8-253.0	White to light gray, foraminifer-bearing nannofossil ooze to nannofossil ooze	Quaternary to middle Miocene
IC	25 2A-18A 29B-31B 1C-18C	226.4-236.0 245.6-344.4 253.0-277.4 305.7-469.0	White to light gray to light greenish gray, foraminifer-bearing nannofossil chalk to nannofossil chalk	middle Miocene to late Oligocene
II	18C-19C	469.0-488.1	Light greenish gray, siliceous foraminifer-bearing nannofossil chalk and chert	middle Eocene

[a] Letters following core number refer to the hole from which core is taken.

curs between iron sulfide and light greenish gray ash(?) layers. In most instances, iron sulfide streaks occur below these layers (but not often above them). This association suggests that the ash(?) layers are a source of iron during diagenesis.

Hole 588A was terminated at about 335 m (Core 588A-18) when the HPC ceased to penetrate, possibly because chert was present. A fist-sized nodule found in Section 588A-18-2 was the only occurrence of chert in Unit I. No chert was found during rotary drilling at an equivalent depth in Hole 588C.

One of the most controversial shipboard sedimentological problems encountered at Site 588 centers on the origin of the microfaults and slickensides observed in Cores 588C-3 through 588C-5. In this interval there are several faults with apparently normal dip-slip offsets of 5 to 10 mm, usually occurring along highly angled surfaces (about 60°). The faces of these surfaces are often slickensided and occasionally mineralized by iron sulfide and possibly rhodochrosite. Two hypotheses for their origin prevail: either the features were produced naturally by tectonism, or the features were produced artificially by drilling. One argument favoring the tectonic origin of these features is the known Neogene tectonism in nearby areas. For example, the Leg 90 water gun seismic profiles illustrate active graben formation extending to Recent times in an area 170 n. mi. north of Site 588. The healed microfaults are also strong evidence for the tectonic origin of most of these features. On the other hand, the interval is quite disturbed by rotary drilling, and a number of cracks are clearly artificial.

Unit II consists of siliceous foraminifer-bearing nannofossil chalks and foraminifer-bearing cherts. This unit was encountered only at the bottom of Hole 588C, and less than one meter of it was recovered. This lithostratigraphic unit is characterized by the presence of siliceous sponge spicules, diatoms, and diagenetic chert. This unit coincides with Unit 2 of DSDP Site 208 (Burns, Andrews, et al., 1973). The color varies from light greenish gray to grayish yellow green. A few burrows occur in samples from Core 588C-19.

PHYSICAL PROPERTIES

Standard DSDP methods (Boyce, 1976; Boyce, 1977) were employed for the measurements of physical properties at Site 588 (see Introduction and Explanatory Notes for specific techniques). The properties measured include sonic velocity, thermal conductivity, and calcium carbonate content. Wet-bulk density, grain density, and porosity were determined by gravimetric analyses, and saturated bulk density was also measured by GRAPE. All of the properties are analyzed and cross-correlated in detail by Morin (this volume).

The values of GRAPE porosity are derived from the GRAPE saturated bulk density results, assuming a grain density of 2.691 g/cm^3. This is a reasonable approximation, since the percentage of $CaCO_3$ in the sediments is very high (Fig. 6A). The porosity data are plotted versus depth (points) in Figure 6B, and are subsequently averaged across each meter (solid line). GRAPE porosity for Holes 588 and 588A is compared with that for Holes 588B and 588C in Figure 6C.

Compressional wave velocities demonstrate a sharp increase at the beginning of Hole 588C (Fig. 6D). These data are correlated with those of Figure 6C in an effort to establish a relationship between P-wave velocity and porosity (Fig. 6E). Combining the GRAPE bulk density profile with the sonic velocity values provides a plot of impedance versus depth (Fig. 6F). This latter figure depicts a smooth, gradual increase in impedance through the 488 m of the sediment column.

SEISMIC STRATIGRAPHY

Figure 7 illustrates portion of the shipboard water gun seismic profile collected during the approach to Site 588. Five acoustic units (A, B, C, D, and E) have been identified, analogous to acoustic Units A to E of Willcox et al., 1980. Acoustic units are correlated with the lithology of Site 588, Units I and II.

Acoustic Unit A appears as an acoustically transparent layer at frequencies recorded on the seismic profile. Faint, coherent reflections occur down to 0.1 s[4] sub-bottom.

Acoustic Unit B (the "chaotic" unit of Willcox et al., 1980) exhibits diffuse, sometimes coherent but generally chaotic reflections. A more reflective zone that occurs between 0.37 and 0.42 s sub-bottom can be traced for some tens of miles to the north on the underway water gun seismic profile.

Acoustic Unit C, comprising high-amplitude, relatively coherent reflectors, is a unit which can be identified throughout the region. The boundary between Unit C and overlying Unit B is relatively sharp. On the Lord Howe Rise, adjacent to and some 160 mi. north of Site 588, the water gun profile shows major graben structures which appear to contain Unit C downfaulted into the grabens.

Acoustic Unit D comprises a high-amplitude, relatively coherent set of reflectors with an appearance similar to that of Unit C. Overlying basement lows (possible graben structures), Unit D is separated from overlying Unit C by a lenticular low-amplitude graben-filling seismic unit (Fig. 7).

Acoustic Unit E is a low-amplitude (relatively transparent) zone overlying acoustic basement, a relationship

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[4] Depths quoted in text as seconds below seafloor have been measured below Site 588.

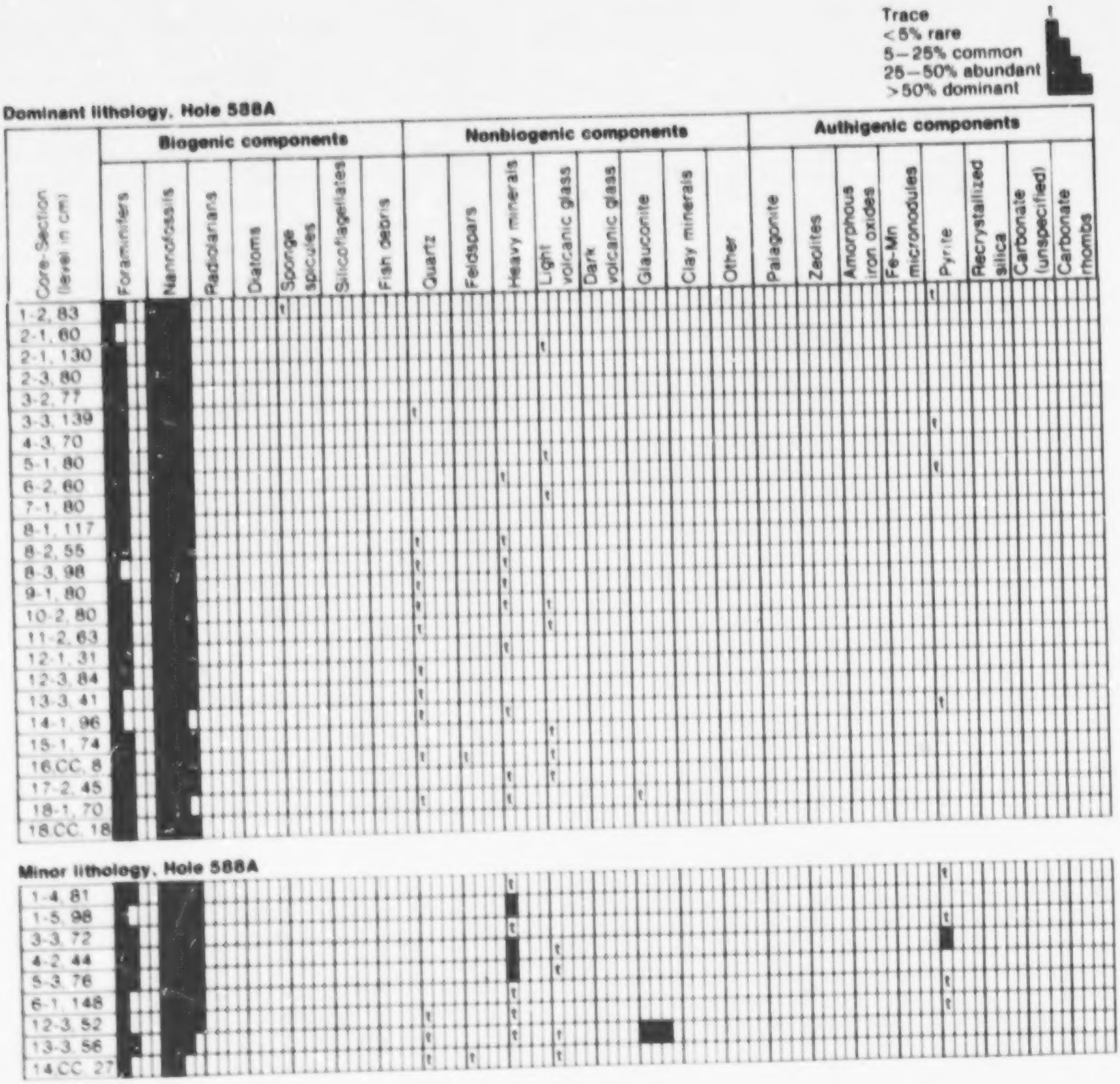


Figure 5. Smear slide summaries, Holes 588A, B, C.

which is not particularly evident in Figure 7. Similar to the transparent zone between Units C and D, Unit E appears to be a graben-filling unit, showing an onlap relationship with basement. This unit is poorly represented or entirely absent over structural highs, where the high-amplitude zones of Units C and D tend to coalesce.

Acoustic basement below Site 588 is inferred to lie at about 0.77 s sub-bottom.

Site 588 was drilled to a total depth of 488.1 m (Hole 588C). The stratigraphic section is divided into two lithologic units.

Unit IA is an oxidized foraminifer-bearing nannofossil ooze of Quaternary age, restricted to the uppermost 6.8 m of section. Unit IB is a light-colored foraminifer-bearing nannofossil ooze to nannofossil ooze, ranging in age from Quaternary to middle Miocene. Unit IC is a middle Miocene to upper Oligocene foraminifer-bearing nannofossil chalk to nannofossil chalk. Unit II comprises a siliceous foraminifer-bearing nannofossil chalk and chert.

An interval velocity of 1700 m/s has been determined by averaging shipboard velocimeter mesurements on cores. The stratigraphic column in Figure 7 has been prepared using this velocity value. However, no positive correlation is apparent between acoustic and lithostratigraphic units, with the possible exception of the Eocene/Oligocene boundary. This boundary is obscured by an interval of strong reflections in the vicinity of Site 588, but the left-hand extremity of the profile on Figure 7 shows a reflector which, on extrapolation to the site, may rep-

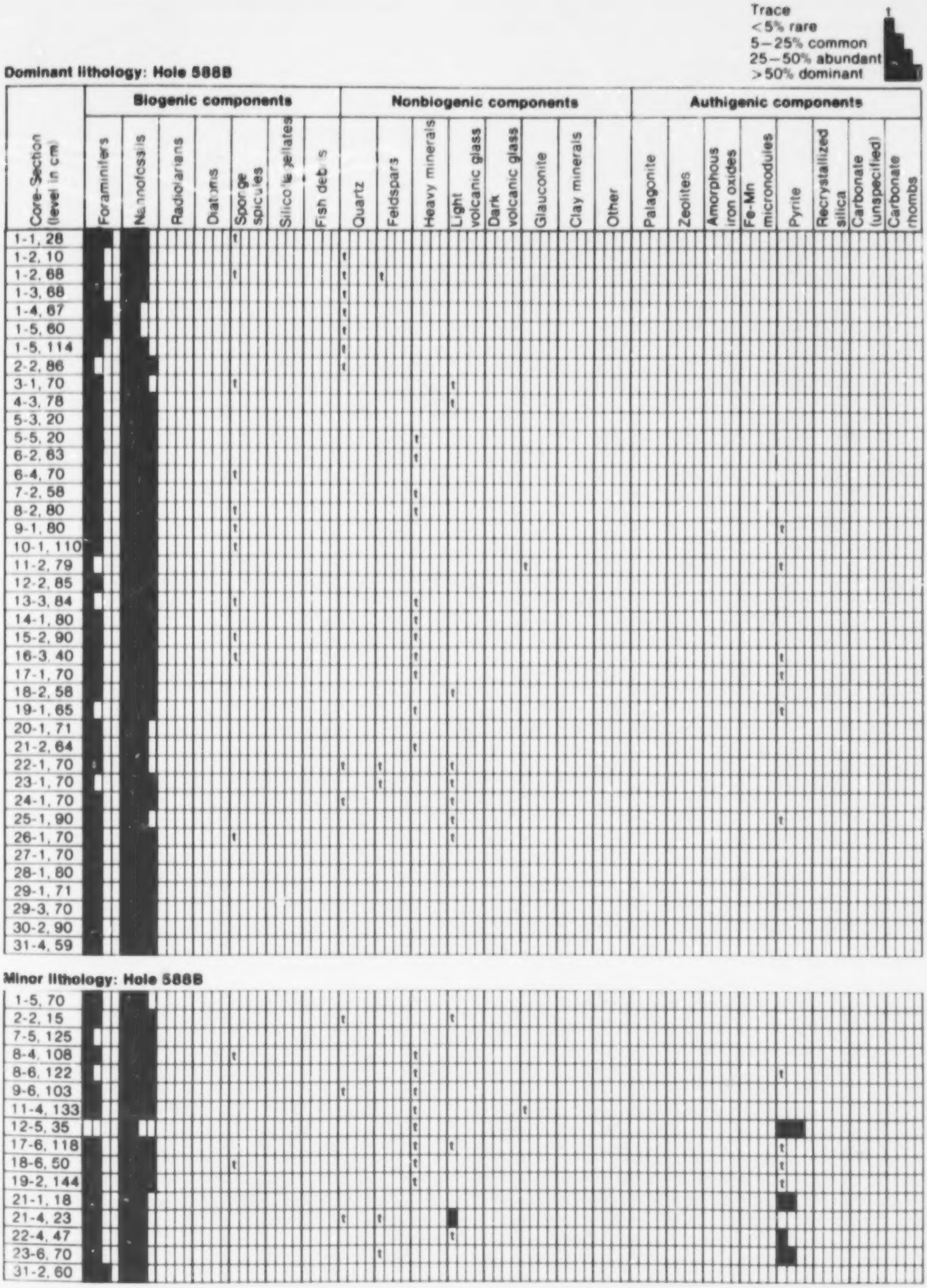


Figure 5. (Continued).

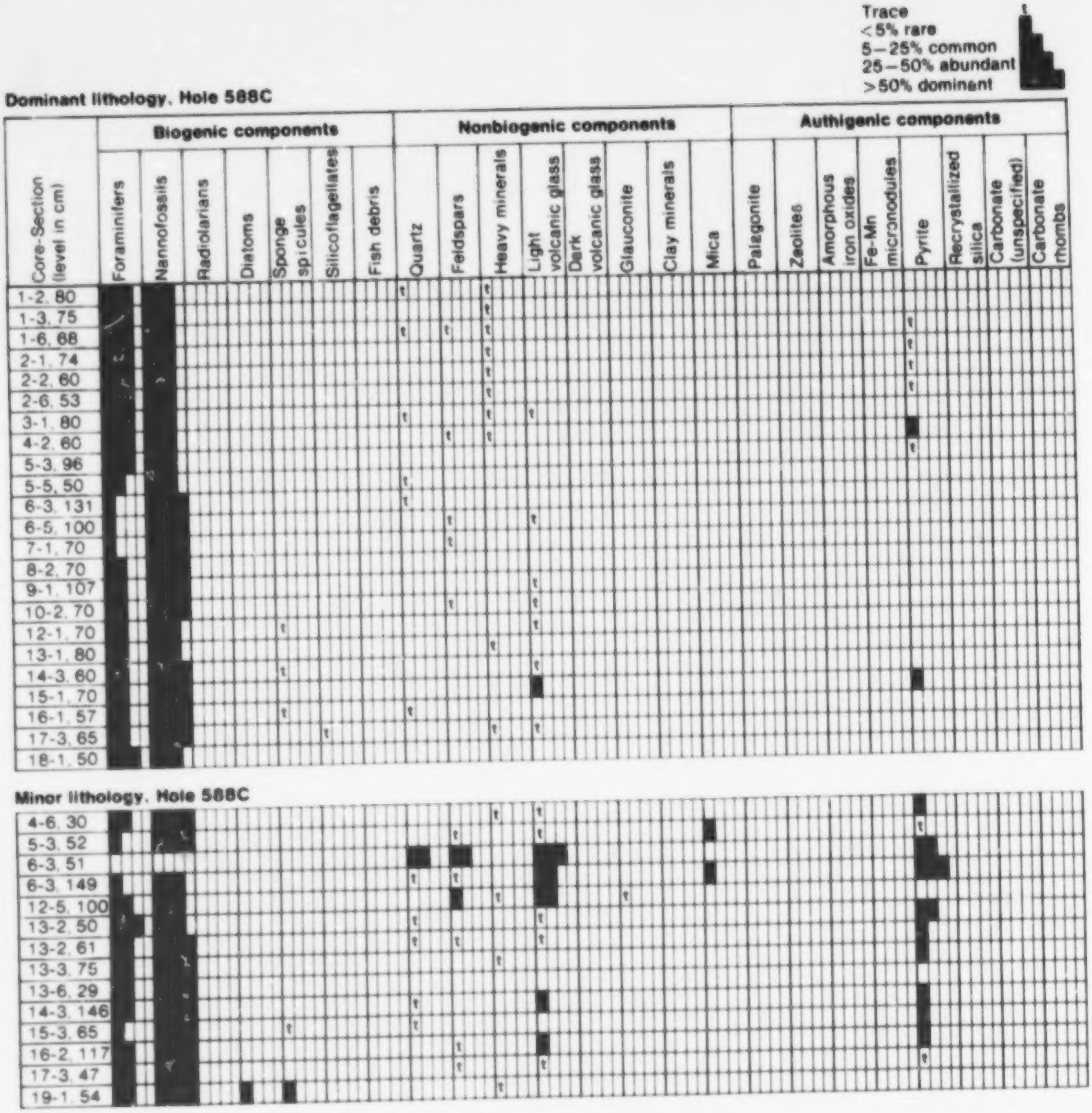


Figure 5. (Continued).

resent the onset of chert development in the middle Eocene; this in turn may correlate with the boundary between acoustic Units C and D.

BIOSTRATIGRAPHY

A complete calcareous sequence from the late Oligocene through Recent was recovered from the four holes drilled at Site 588. It is underlain by a siliceous-calcareous sequence of middle Eocene age from which it is separated by a disconformity at approximately 470 m sub-bottom. The deepest hole, Hole 588C, was terminated at 488.1 m BSF in middle Eocene sediments. The completeness of the sequence, which is far superior to that in Hole 208, drilled on Leg 21, resulted in a very detailed planktonic foraminifer and calcareous nannoplankton zonation and has provided material for an evaluation of the paleoenvironmental history of warm subtropical waters of the southern hemisphere during the late Oligocene to Recent. The calcareous sediments between 0 and about 470 m contain exclusively foraminifers, calcareous nannoplankton, calcareous dinoflagellates (calcispheres), and at certain levels also ostracodes and pteropods. Below the disconformity at 470 m, down to the terminal depth of 488.1 m, foraminifers and calcareous nannoplankton are associated with diatoms, radiolarians, silicoflagellates, ebridians, and sponge spicules in the middle Eocene.

Preservation of the calcareous fossils is excellent in the upper part of the sequence, and is fairly good for the foraminifers as well in the lower part of the calcareous sequence, where calcareous nannoplankton show considerable calcite overgrowth, especially in the upper Oligocene sediments. Preservation is good again for the calcareous nannoplankton in the middle Eocene, where the sequence contains a considerable amount of siliceous constituents. Calcareous nannoplankton and planktonic foraminiferal zones in the four holes of Site 588 are correlated in Figure 8.

Foraminifers

Planktonic Foraminifers

Zones

The zonal scheme used at Site 588 has been adapted from Kennett (1973) and Srinivasan and Kennett (1981a, b) (Fig. 9). The following changes have been made.

Globorotalia puncticulata Zone: It appears that the zonal marker made a late appearance at Site 588 as compared to the temperate sites of the southwest Pacific where it evolved; its immediate ancestor *Globorotalia sphericomiozoa* is not present.

Globorotalia plesiotumida Zone: At Site 588 *G. conomiozea* with a squarer outline in peripheral view made a late appearance within the range of the *G. margaritae* Zone and so the *G. conomiozea* Zone of Kennett (1973) and Srinivasan and Kennett (1981a, b) was not used. The *G. plesiotumida* Zone of the late Miocene is therefore equivalent to the lower part of their *G. conomiozea* Zone and the entire *Globigerina nepenthes* Zone.

Globorotalia fohsi s.l. Zone is equivalent to the upper part of the *Orbulina suturalis* Zone of Kennett (1973) and to the *Globorotalia fohsi* s.l. Zone and the *G. peripheroacuta* Zone of Srinivasan and Kennett (1981a, b). The main reason for "lumping" the zones together was the difficulty in consistently identifying the keeled *G. fohsi* in the upper part of the *G. fohsi* s.l. Zone at Site 588.

The following zones have been added to the lower part of the sequence in the Oligocene.

Globigerina angulisuturalis Zone: This is a gap zone, with the base defined by the extinction of *Chiloguembelina cubensis* and the top by the first appearance of *Globorotalia kugleri*.

Chiloguembelina cubensis Zone: The top is defined by the extinction of the zonal marker and the base is undefined. The index species *G. munda* is present in the zone.

Faunas

Globorotalia truncatulinoides Zone: The zone fossil is common, as are *Globigerina calida, Globorotalia inflata, G. menardii, G. tumida*, and *Pulleniatina obliquiloculata*.

Globorotalia truncatulinoides–G. tosaensis Zone: The zone is marked by the overlap of the two zonal taxa, which are common in the zone. Other common species include *G. inflata* and *Neogloboquadrina dutertrei*.

Globorotalia tosaensis Zone: The zone fossil is abundant. There is evidence at the base of the zone of its evolution from *G. crassaformis*. Other important species in the zone include *P. obliquiloculata* and *G. menardii; Globigerinoides extremus* and *Dentoglobigerina altispira* became extinct in the lower part of the zone.

Globorotalia inflata Zone: The zone fossil is well represented in the zone, but its entry at the base was probably late compared with its evolutionary appearance further south in the southwest Pacific. Other species present include *Globorotalia menardii, G. crassaformis*, and *Neogloboquadrina dutertrei*.

Globorotalia crassaformis Zone: The zone fossil made a late appearance compared with its evolutionary appearance further south; other species present in the zone, included *Globorotalia pliozea*, which became extinct in the lower part of the zone, and *Globigerina nepenthes*.

Globorotalia puncticulata Zone: The zone fossil is rare in the zone and occurred with *G. crassaformis, G. tumida*, and *P. primalis*.

Globorotalia margaritae Zone: This zone is well represented with excellent faunas which include the zone fossil. *Globorotalia cibaoensis* became extinct within the zone and *P. primalis* made its entry in the lower part of the zone.

Globorotalia plesiotumida Zone: The zone fossil is comparatively rare. This was especially true in the lower part of the zone; other species in the zone include *G. miotumida* and *G. menardii*.

Neogloboquadrina continuosa Zone: The zone fossil is fairly rare within the zone and became extinct at the top of the zone; other important species include *Candeina nitida, Globigerinatella aequilateralis*, and *N. nympha*, the probable immediate ancestor of *N. acostaensis; Globoquadrina dehiscens* became extinct within the zone.

Globorotalia mayeri Zone: The zone fossil is fairly rare within the zone, which marks the first appearance of *Neogloboquadrina*; other species present include *G. menardii, G. miotumida*, and *G. panda*.

Globorotalia fohsi s.l. Zone: The zonal markers include *G. peripheroacuta* and *G. fohsi* s.l.; the latter form occurs sporadically throughout the zone. Both *G. miotumida, G. panda*, and *G. menardii* made their first appearance within the zone, whereas *G. miozea* became extinct.

Orbulina suturalis Zone: The zone fossil is common within the zone. Also present are *G. peripheroronda* and *G. miozea*.

Praeorbulina glomerosa curva Zone: The zone fossil is common within the zone, in association with *G. praescitula, G. miozea*, and *G. siakensis*.

Globorotalia miozea Zone: The zone fossil is common within the zone; other taxa include *Globoquadrina dehiscens, Globorotalia praescitula*, and *G. peripheroronda*, which made its initial appearance in the zone.

Catapsydrax dissimilis Zone: The zone fossil is common in the zone and occurs in association with *G. semivera* and *G. siakensis*.

Globoquadrina dehiscens Zone: The zone fossil is common within the zone and occurs in association with *Globigerinoides primordius, G. altiaperturus*, and *Globorotalia kugleri*.

Globigerinoides primordius Zone: The zone fossil is rare and occurs with *Globigerina woodi, Globorotalia*

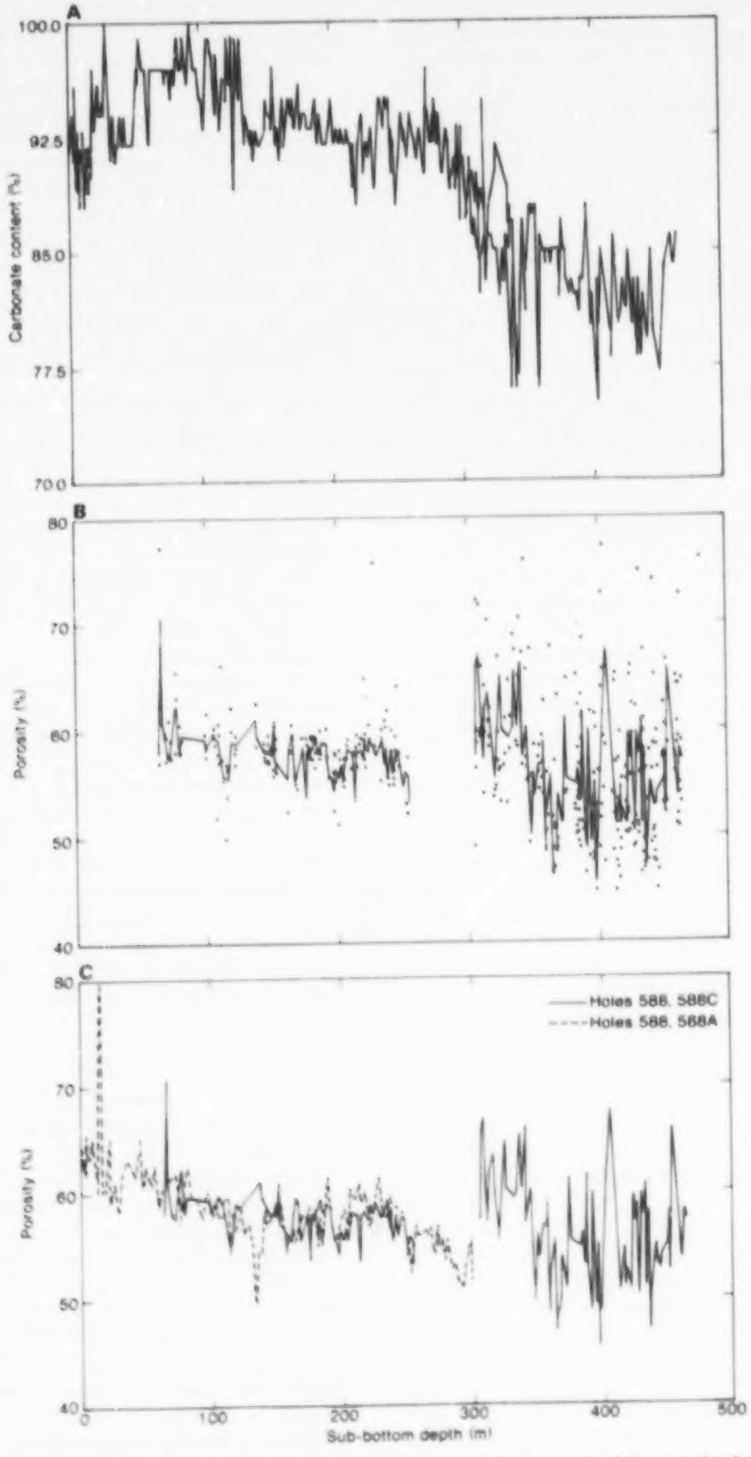


Figure 6. Physical properties, Site 588. A. Carbonate content versus sub-bottom depth for Site 588. B. GRAPE porosity versus sub-bottom depth for Holes 588B and 588C. C. GRAPE porosity versus sub-bottom depth for Holes 588, 588A, 588B and 588C. D. Compressional velocity versus sub-bottom depth for Site 588. E. Porosity versus compressional velocity for Site 588. F. Acoustic impedance versus sub-bottom depth for Site 588.

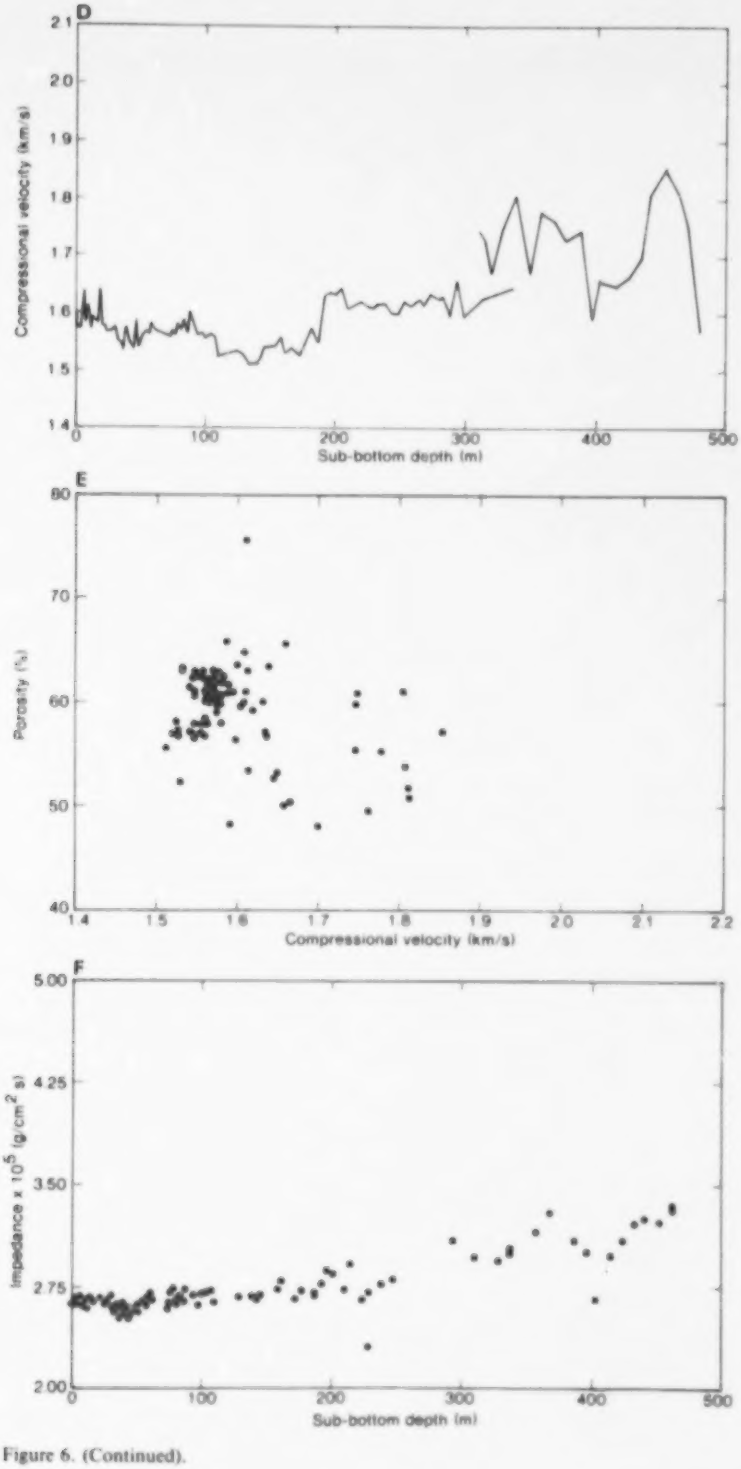


Figure 6. (Continued).

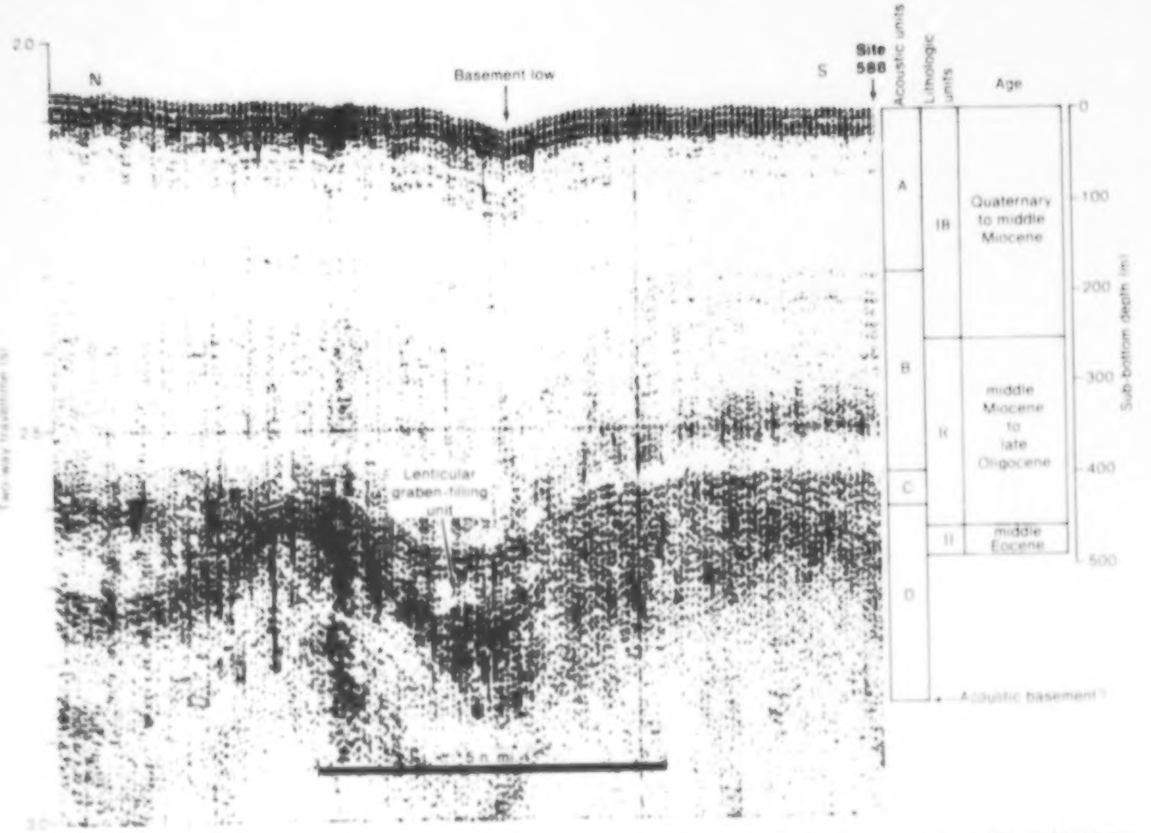


Figure 7. Comparison of acoustic Units A-E with lithologic Units I-II cored at Site 588; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1700 m/s.

kugleri, and *Globoquadrina* sp., the possible ancestor of *G. dehiscens*.

Globigerina angulisuturalis Zone: The zone fossil is common within the zone. The related species *Globigerina ciperoensis* is very rare. Other species present include *G. euapertura*, *Globorotalia nana*, *Globorotaloides suteri*, and *Globorotalia testarugosa*.

Chiloguembelina cubensis Zone: The zone fossil is common and occurs with *G. munda*; *G. opima* is rare.

Paleobiogeography

The late Oligocene yields a cosmopolitan fauna with an element of the southern cooler-water species such as *Globigerina woodi* and *Globorotalia munda*; the fauna lacks *Globigerina ciperoensis* and there are only a few specimens of *Globorotalia opima*.

The early Miocene was dominated by cooler-water southern taxa such as *G. zealandica* and *G. miozea* and marked by the absence of such warm-water forms as *Catapsydrax stainforthi*, *Globigerinatella insueta*, and *Hastigerinella bermudezi*.

The middle Miocene keeled *Globorotalia* fauna is dominated by the *G. miotumida* group and to a much lesser extent by *G. menardii*; the tropical *G. fohsi lobata* and *G. fohsi robusta* are absent.

The late Miocene appears to have been cooler, because of the predominance of the southern *G. miotumida* group and the absence of such species as *Pulleniatina primalis*.

There was a marked change in fauna at about the Miocene/Pliocene boundary; *G. conomiozea* with a squarer outline in peripheral view became extinct and the tropical *G. tumida* appeared.

The Pliocene-Pleistocene forms were a mixture of warm subtropical-tropical species such as *G. tumida*, *G. menardii*, and *P. obliquiloculata* with a minor cooler-water element represented by *G. inflata* and *Neogloboquadrina pachyderma*.

Major Stratigraphic Boundaries

At this site the major boundaries were marked by the following species.

1. Pliocene/Pleistocene boundary: first appearance of *Globorotalia truncatulinoides*.

2. Miocene/Pliocene boundary: Kennett (1973) and Srinivasan and Kennett (1981a, b) placed the boundary at the first appearance of *G. margaritae*, which coincided with the extinction of *G. conomiozea*. In Site 588 we have, instead, observed overlapping ranges of *G. margaritae* and a local morphotype of *G. conomiozea* and have placed the boundary after the extinction of *G. conomio-*

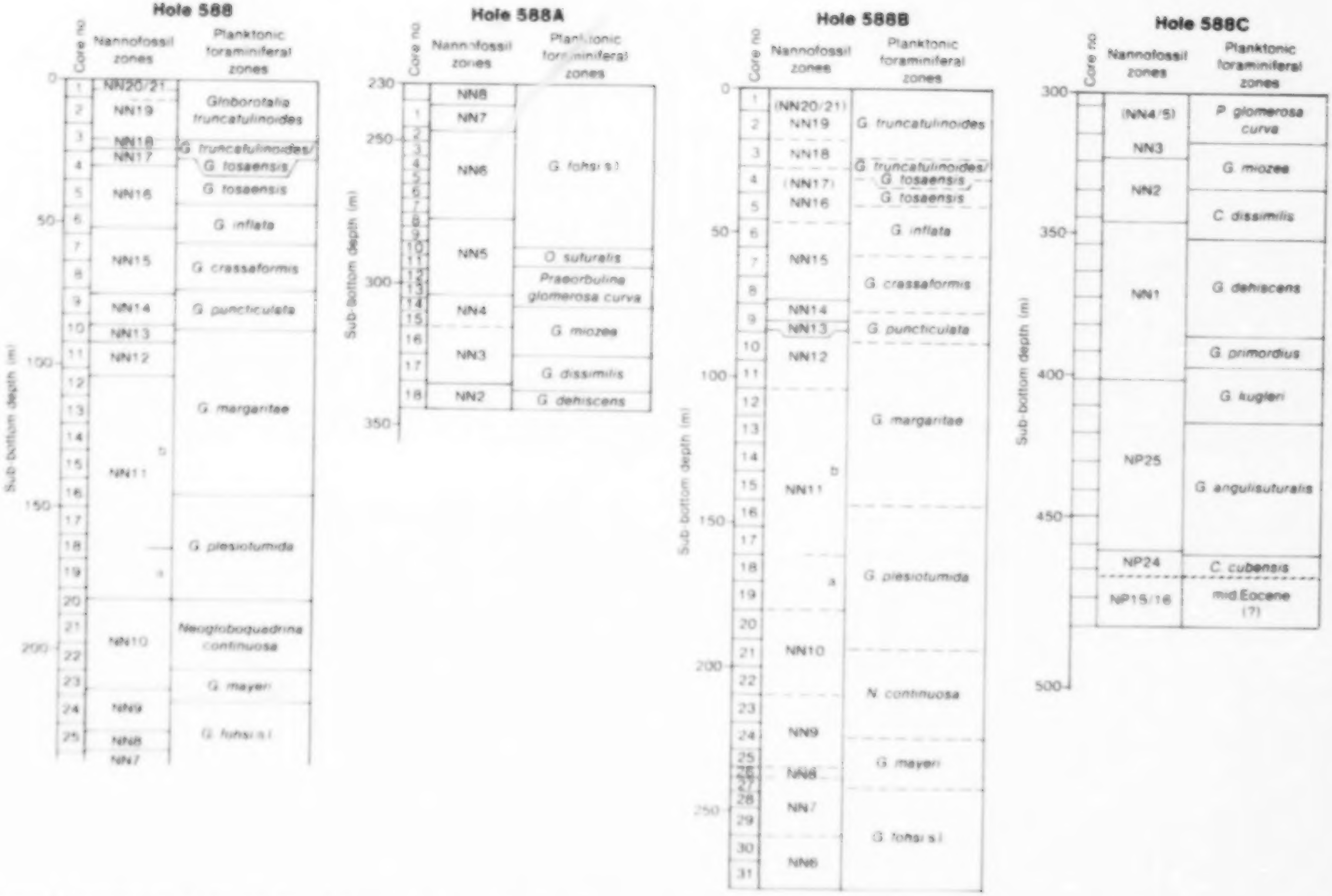
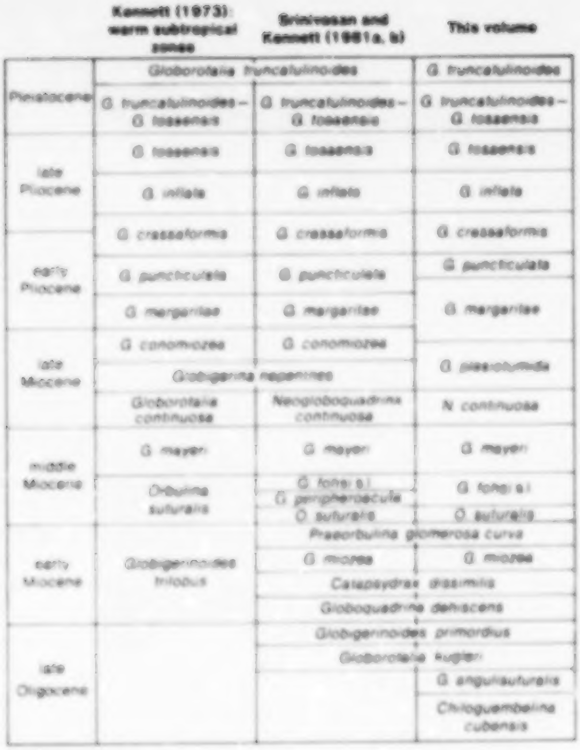

Hole 588
Core no
Nannofossil zones
Planktonic foraminiferal zones
Sub-bottom depth (m)
0
50
100
150
200
NN20/21
NN19
NN18
NN17
NN16
NN15
NN14
NN13
NN12
NN11
b
a
NN10
NN9
NN8
NN7
Globorotalia truncatulinoides
G. truncatulinoides/ G. tosaensis
G. tosaensis
G. inflata
G. crassaformis
G. puncticulata
G. margaritae
G. plesiotumida
Neogloboquadrina continuosa
G. mayeri
G. fohsi s.l.
Hole 588A
230
250
300
350
NN8
NN7
NN6
NN5
NN4
NN3
NN2
G. fohsi s.l.
O. suturalis
Praeorbulina glomerosa curva
G. miozea
G. dissimilis
G. dehiscens
Hole 588B
(NN20/21)
NN19
NN18
(NN17)
NN16
NN15
NN14
NN13
NN12
NN11
NN10
NN9
NN8
NN7
NN6
G. truncatulinoides
G. truncatulinoides/ G. tosaensis
G. tosaensis
G. inflata
G. crassaformis
G. puncticulata
G. margaritae
G. plesiotumida
N. continuosa
G. mayeri
G. fohsi s.l.
Hole 588C
300
350
400
450
500
(NN4/5)
NN3
NN2
NN1
NP25
NP24
NP15/16
P. glomerosa curva
G. miozea
C. dissimilis
G. dehiscens
G. primordius
G. kugleri
G. angulisuturalis
C. cubensis
mid Eocene (?)

Figure 8. Biostratigraphy for Site 588. No radiolarians were encountered.



	Kennett (1973): warm subtropical zones	Srinivasan and Kennett (1981a, b)	This volume
Pleistocene	Globorotalia truncatulinoides		G. truncatulinoides
	G. truncatulinoides – G. tosaensis	G. truncatulinoides – G. tosaensis	G. truncatulinoides – G. tosaensis
late Pliocene	G. tosaensis	G. tosaensis	G. tosaensis
	G. inflata	G. inflata	G. inflata
	G. crassaformis	G. crassaformis	G. crassaformis
early Pliocene	G. puncticulata	G. puncticulata	G. puncticulata
	G. margaritae	G. margaritae	G. margaritae
late Miocene	G. conomiozea	G. conomiozea	G. plesiotumida
	Globigerina nepenthes		
	Globorotalia continuosa	Neogloboquadrina continuosa	N. continuosa
middle Miocene	G. mayeri	G. mayeri	G. mayeri
	Orbulina suturalis	G. fohsi s.l.	G. fohsi s.l.
		G. peripheroacuta	
		O. suturalis	O. suturalis
early Miocene	Globigerinoides trilobus	Praeorbulina glomerosa curva	
		G. miozea	G. miozea
		Catapsydrax dissimilis	
		Globoquadrina dehiscens	
late Oligocene		Globigerinoides primordius	
		Globorotalia kugleri	
			G. angulisuturalis
			Chiloguembelina cubensis

Figure 9. Planktonic foraminiferal zones used at Site 588.

zea. This level also coincides with the first appearance of *G. tumida*.

3. Oligocene/Miocene boundary: first appearance of *Globoquadrina dehiscens* as in Srinivasan and Kennett (1981b, 1983).

Benthic Foraminifers

Benthic foraminifers were examined in aliquots of the fractions less than 63 μm in core catchers from Holes 588, 588A, and 588C (Table 3). The benthics are well preserved in most core catchers down to the lower Miocene (Section 588A-2 through Sample 588A-18,CC and 588C-8 through 588C-19,CC). Below this point diagenetic alteration of the sediments has removed nearly 50% of the coarse fraction and, in the lower samples, a large percentage of the intermediate size-fraction as well.

From the top of the section down to the middle Miocene, faunas are very similar; they are dominated by species of *Oridorsalis*, *Globocassidulina*, *Pullenia*, and *Melonis*. Diversity varies from a high of 25 species in the late Pliocene (Sample 588-6,CC) to a low of four species in a rich plankton ooze at the base of the *Globorotalia plesiotumida* Zone (Sample 588-19,CC). In general, both the diversity of the benthic faunas and the abundance of benthic specimens in the aliquots decrease down the section as the preservation of the carbonates worsens.

In the Pliocene (Samples 588-4 through 588-15,CC) there are three episodes of marked faunal change. In the *G. inflata* Zone (equivalent to the NN15/NN16 boundary in Sample 588-6,CC) there occurs a marked increase in both diversity and faunal abundance and many species disappear from the faunas. These include *Anomalinoides semipunctata*, *Cibicides lobatulus*, *Osangularia culter*, *Karreriella bradyi*, *Hopkinsina mioindex*, and *Stilostomella insecta*. Two of these species, *O. culter* and *A. semipunctata*, are very rare at this site, appear for a short time only in the lower and mid-Pliocene, and then disappear. Both *O. culter* and *A. semipunctata* were found at the shallow Site 587, but not at the deeper Site 586. Their presence at the initiation of the glacial Pliocene at Site 588 may represent downward migration of these species and/or increased downslope movement of sediments.

A second episode of increased faunal abundance (Sample 588-8,CC) in the *G. crassaformis* Zone is accompanied by the unusual appearance of two species, *Pullenia quinqueloba* and *Melonis pompiliodes*, which are typical of the faunas at the deeper Site 586, but do not appear in the faunas from the shallow Site 587. The rare appearances of these species, as in Sample 588-8,CC, may indicate upward migration of benthics because of some ecologic change. The proportions of other species in the samples need to be counted to test this idea.

In the top of the *G. margaritae* Zone (Sample 588-10,CC), there is an episode of faunal overturn involving the upward disappearance of several important species: *Ehrenbergina pacifica*, *Uvigerina spinulosa*, and *Rectuvigerina multistriata*, among others. At the shallower Site 587, *R. multistriata* disappears later, at the beginning of the glacial (= NN15/NN16).

In the Miocene there are also three episodes of marked faunal change: at the base of the *Neogloboquadrina continuosa* Zone, in the *G. fohsi* s.l. Zone, and in the *G. miozea* Zone. Otherwise the Miocene faunas are very consistent. Diversity and faunal abundance are consistent except in those poorly preserved samples lower in the section. Very few new species appear above the base of the middle Miocene.

Toward the base of the *N. continuosa* Zone (Cores 588-21 through 588-23) there is a second influx of *M. pompilioides*, *P. quinqueloba*, and several other species suspected of representing a deeper faunal influence. There is no apparent change in benthic diversity or abundance during this faunal change.

Faunal changes in the *G. fohsi* s.l. Zone (Samples 588A-2 through 588A-9 and 588C-1 through 588C-9) are difficult to evaluate because carbonate preservation worsens in this zone. Diversity and faunal abundances are generally lower than in overlying samples. The character of faunas alters slightly because *Ehrenbergina* spp., small virgulinids, large nodosarids and *Quinqueloculina* increase in abundance upward. The significance of these forms is not known. In addition, several species disappear from the faunas at this time; these include *Heterolepa trinitatensis*, *Siphonodosaria modesta*, *Bulimina tuxpamensis*, *B. semicostata*, and *Cibicidoides* sp. Upward migration of benthic species is not evident in the material seen so far.

The elimination of typical Eocene–Oligocene benthic species occurs in the base of the *G. miozea* Zone (588A-15 to 588A-16,CC). In these samples both faunal abundance and diversity are highest for the early Miocene. Species which terminate in this zone are *Planulina renzi*, *Sipho-*

nina pulchra, H. hunteri, B. jarvisi, O. mexicana, and *Plectofrondicularia* sp.

The lowermost Miocene and the Oligocene at Holes 588A and 588C cannot be compared with overlying sediments because of the degree of dissolution in the older samples. In both holes sediments of this age have lost nearly 50% of their coarse fractions, including a large percentage of benthic species. In the Oligocene (588C-9 through 588C-17,CC) the intermediate size-fraction is also largely missing. Glauconite is occasionally present and a large proportion of the fossils are fragmented. Benthic species present include *Oridorsalis umbonatus, Globocassidulina subglobosa, C. tuxpamensis, Pullenia coryelli, B. semicostata,* and *P. quadriloba*.

Calcareous Nannoplankton

Core-catcher samples along with enough additional samples to determine zonal boundaries were examined for calcareous nannoplankton. All zonal indicators are present, with the exception of *Helicosphaera ampliaperta*. The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis*. Calcareous nannoplankton are abundant and well preserved throughout the upper part of the section.

Hole 588

Pleistocene

The presence of *Emiliania huxleyi* in Sample 588-1-1, 85–86 cm places this sample in the late Pleistocene *Emiliania huxleyi* Zone (NN21). Sample 588-1-2, 85–86 cm is placed in the late Pleistocene *Gephyrocapsa oceanica* Zone (NN20). The presence of *E. ovata* and the absence of *Calcidiscus macintyrei* in Samples 588-1-3, 85–86 cm and 588-1,CC place these samples in the upper subzone of the early Pleistocene *E. ovata* Zone (NN19b). The addition of *C. macintyrei* in Samples 588-2-1, 85–86 cm to 588-3-4, 0–1 cm places these samples in the lower subzone of the *E. ovata* Zone (NN19a).

Pliocene

The last occurrence of *Discoaster brouweri* in Sample 588-4-2, 0–1 cm and the last occurrence of *D. pentaradiatus* in Sample 588-3,CC place Samples 588-3-5, 0–1 cm and 588-4-1, 0–1 cm in the late Pliocene *Discoaster brouweri* Zone (NN18). The presence of *D. brouweri* together with *D. pentaradiatus* in Sample 588-4-2, 0–1 cm places this sample in the late Pliocene *D. pentaradiatus* Zone (NN17).

The last occurrence of *Reticulofenestra pseudoumbilica* in Sample 588-6-6, 0–1 cm places Samples 588-4-3, 0–1 cm to 588-6-5, 0–1 cm in the late Pliocene *Discoaster surculus* Zone (NN16). Samples 588-6-6, 0–1 cm to 588-9-2, 0–1 cm, above the last occurrence of *Amaurolithus tricorniculatus*, are placed in the early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). The interval from Sample 588-9-3, 0–1 cm to the first occurrence of *D. asymmetricus* in Sample 588-11-1, 0–1 cm is placed in the early Pliocene *D. asymmetricus* Zone (NN14). The interval from Sample 588-11-2, 0–1 cm to the first occurrence of *Ceratolithus rugosus* in Sample 588-11-3, 0–1 cm in placed in the early Pliocene *Ceratolithus rugosus* Zone (NN13). The early Pliocene *Amaurolithus tricorniculatus* Zone (NN12) includes Samples 588-11-4, 0–1 cm to 588-12-1, 0–1 cm above the last occurrence of *D. quinqueramus*.

Miocene

The last occurrence of *Discoaster quinqueramus* in Sample 588-12-2, 0–1 cm and the first occurrence of *Amaurolithus primus* in Sample 588-18-3, 0–1 cm places Samples 588-12-2, 0–1 cm to 588-18-3, 0–1 cm in the upper subzone of the late Miocene *Discoaster quinqueramus* Zone (NN11b). The interval from Sample 588-18-4, 0–1 cm to the first occurrence of *D. quinqueramus* in Sample 588-20-7, 0–1 cm is placed in the lower subzone of the late Miocene *D. quinqueramus* Zone (NN11a). Samples 588-20,CC to 588-23-4, 0–1 cm, above the last occurrence of *D. hamatus*, are placed in the late Miocene *D. calcaris* Zone (NN10).

The middle Miocene *D. hamatus* Zone (NN9) includes Samples 588-23-5, 0–1 cm to 588-25-3, 0–1 cm, based upon the occurrence of *D. hamatus*. The interval from Sample 588-25-4, 0–1 cm to the first occurrence of *Catinaster coalitus* in Sample 588-25-6, 0–1 cm is placed in the middle Miocene *Catinaster coalitus* Zone (NN8). Sample 588-25,CC is placed in the middle Miocene *D. kugleri* Zone (NN7). Hole 588 was terminated at a depth of 236.0 m BSF.

Hole 588A

Hole 588A continues downsection from where Hole 588 ended. However, the presence of *Catinaster coalitus* in Sample 588A-1-1, 0–1 cm suggests a slight stratigraphic overlap between the two holes, because its apparent first occurrence was in Sample 588-25-6, 0–1 cm. The middle Miocene *Discoaster kugleri* Zone (NN7) is continued from Sample 588A-1-2, 0–1 cm to the first occurrence of *Discoaster kugleri* in Sample 588A-2-4, 0–1 cm. The interval from Samples 588A-2,CC to 588A-8,CC, above the last occurrence of *Sphenolithus heteromorphus* in Sample 588A-9-1, 0–1 cm, is placed in the middle Miocene *D. exilis* Zone (NN6). the interval from Sample 588A-9-1, 0–1 cm to the first occurrence of *D. exilis* in Sample 588A-12,CC is placed in the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). The early Miocene *Helicosphaera ampliaperta* Zone (NN4) includes Samples 588A-13,CC to 588A-15,CC, above the last occurrence of *S. belemnos* in Sample 588A-16,CC. The interval from Samples 588A-15,CC to 588A-17,CC, above the last occurrence of *Triquetrorhabdulus carinatus* in Sample 588A-18-1, 0–1 cm, is placed in the early Miocene *S. belemnos* Zone (NN3). Samples 588A-18-1, 0–1 cm and 588A-18,CC are placed in the early Miocene *D. druggii* Zone (NN2). Hole 588A was terminated at a depth of 344.4 m BSF.

Hole 588B

Hole 588B duplicates all of Hole 588 and the upper part of Hole 588A; therefore, only the 31 core-catcher samples were examined. The zonal boundaries (NN21/

NN6) encountered in this hole are essentially the same as those of Holes 588 and 588A. Hole 588B was terminated at a depth of 277.4 m BSF.

Hole 588C

Hole 588C stratigraphically overlaps the lower part of Hole 588A and begins with Sample 588C-1,CC in the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). The interval from Sample 588C-2-1, 0–1 cm, below the first occurrence of *Discoaster exilis* in Sample 588C-1,CC to 588C-2-5, 0–1 cm above the last occurrence of *Sphenolithus belemnos* in Sample 588C-2-6, 0–1 cm is placed in the early Miocene *Helicosphaera ampliaperta* Zone (NN4). The presence of *S. belemnos* and the absence of *Triquetrorhabdulus carinatus* in the interval from Sample 588C-2-6, 0–1 cm to 588C-3-6, 0–1 cm places these samples in the early Micene *S. belemnos* Zone (NN3). The interval from the last occurrence of *T. carinatus* in Sample 588C-3,CC and the first occurrence of *D. druggii* in Sample 588C-5-1, 21–22 cm is placed in the early Miocene *Discoaster druggii* Zone (NN2). Samples 588C-5-2, 0–1 cm to 588C-10,CC, above the late Oligocene in Sample 588C-10-4, 0–1 cm, are placed in the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1).

The Oligocene/Miocene boundary, taken at the base of nannoplankton Zone NN1 (*T. carinatus* Zone) was encountered at approximately 400 m sub-bottom in Hole 588C. The last occurrences of *Helicosphaera recta, Sphenolithus ciperoensis*, and *Zygrhablithus bijugatus* were found in the lower part of Core 588C-10. In 588C-17 *S. distentus* and *S. predistentus* occur together with *S. ciperoensis*, indicating the presence of Zone NP24 (*Sphenolithus distentus* Zone).

Sphenoliths are not very common in the late Oligocene at this site, but this may be the result of the poor preservation in certain levels. *Z. bijugatus*, which is known to occur in shallow water, is rather common in the entire late Oligocene. Rare reworked Eocene nannoplankton were found in most late Oligocene samples.

At the top of Core 588C-18, a disconformity was noted between the upper and middle Eocene. The Eocene assemblage, also present in the lowest Core 588C-19, contains, among others, *D. barbadiensis, Reticulofenestra umbilica, Chiasmolithus solitus, Neococcolithus dubius*, and *C. grandis*, indicating a position within nannoplankton Zones NP15 (*Chiphragmalithus alatus* Zone) and NP16 (*D. tani nodifer* Zone). In the late Oligocene, the calcareous nannoplankton is heavily overgrown by secondary calcite, discoasters showing alternating rays fused together and sphenoliths partly fragmented in certain levels. The preservation of calcareous nannoplankton in the middle Eocene is fairly good again, probably because siliceous biogenic constituents, are present.

Diatoms and Silicoflagellates

Diatoms and silicoflagellates were found only in the middle Eocene part of Hole 588C (Cores 588C-18 and 588C-19) and are associated with ebridians and sponge spicules. Diatoms are especially common in Core 588C-19, and include representatives of the genera *Triceratium, Actinoptychus, Trochosira*, and *Thalassiosira* among the well-diversified assemblage. Silicoflagellates were encountered in several samples of 588C-19. The assemblage, containing *Naviculopsis foliacea* and *Corbisema spinosa*, can be placed in the middle Eocene *Naviculopsis foliacea* Zone.

Radiolarians

Radiolarians occur only in the middle Eocene part of Hole 588C (Cores 18 and 19).

PALEOMAGNETISM

All well-preserved core sections (i.e., those not fluid or obviously deformed) from Holes 588, 588A, and 588B were measured on the shipboard Digico long-core spinner magnetometer. Apart from the regions of higher intensity (discussed below), the signal was not sufficiently above the noise and contamination levels to give reproducible results in adjacent cores. Long-core measurements were discontinued after this site.

Holes 588, 588A, and 588C were subsampled at two specimens per section (usually), and Hole 588B at one specimen per section. Laboratory NRM measurements have been completed on Holes 588 and 588A (Barton and Bloemendal, this volume). Absolute orientations were attempted on most cores using the Kuster tool, with results as follows: for Hole 588, 21 attempts, 15 successes; for Hole 588A, 8 attempts, all successful; for Hole 588B, 16 attempts, 9 successes and 2 suspect results. This success rate is better than has often been obtained but still needs to be improved.

Intensities of magnetization were generally very low, though noticeably higher than for previous sites on this leg. NRM statistics for the sequence measured are presented in Table 3.

In common with other sites, there is a high-intensity zone (1– ~ 15 μG), at the top of the sequence, but here it is longer, extending to the bottom of Core 588-4. Intensities then become extremely weak (typically 0.05 μG), with high directional scatter down to Core 588-21 near the mid/late Miocene boundary. Below this, intensities increase monotonically to values of around 15 μG at the bottom of the section. Prominent intensity spikes were common in the sequence. The most obvious ones in the subsample data are listed in Table 4. There was no general correlation between these "high" intensity spikes and the occurrence of ash layers and iron sulfide nodules. One exception was the prominent ash layer in Core 588-23-2, 145 cm. Iron sulfide nodules removed from various cores had only weak magnetic moments, sometimes barely higher than that of the surrounding sediments. This suggests that pyrrhotite, the only common ferromagnetic iron sulfide, is not a major component.

Table 3. NRM statistics at Site 588.

	Hole 588	Hole 588A
Geometric mean intensity (μG)	0.150	1.552
Scalar mean inclination	−5.0 ± 39.7°	−6.7 ± 51.6° s.d.
Axial dipole inclination	−44.4°	—
Mean angle between repeats	4.6°	—

Table 4. Prominent magnetization intensity spikes observed in Hole 588.

Core-Section (level in cm)	Depth (m)	Intensity (μG)
2-1, 25	5.85	14.548
2-5, 100	12.60	3.275
4-5, 125	32.05	3.044
5-7, 125	44.65	1.368
9-1, 25	73.05	0.308
9-5, 25	79.05	0.283
11-3, 125	96.25	0.215
11-6, 25	99.75	0.383
12-6, 125	110.35	0.523
13-1, 25	111.45	0.916
13-2, 125	113.95	0.327
14-3, 25	124.05	0.468
14-6, 125	129.55	0.388
19-6, 125	177.55	0.441
21-3, 125	192.25	0.341
23-2, 25	208.95	1.642

Note: Other spikes were apparent in the long-core records.

It was possible to identify a polarity stratigraphy only down to the end of the Gilbert Chron (Fig. 10A). Below this, to the top of the high-intensity zone (around Core 588-22), directions were more scattered and no unambiguous polarity interpretation was possible. It may be possible to improve on this when results from the adjacent HPC become available. Below Core 588-21 it was again possible to identify a polarity stratigraphy (Fig. 10A), but it is not clear how this should be matched to the polarity time scale. The very long normal-polarity interval in Cores 588-24 and -25 would appear to correspond to Chron 9 (8.92 to 10.42 m.y.), but this interpretation conflicts with the foraminifer and nannoplankton zones. The quality of the paleomagnetic record deteriorates markedly in the denser sediments cored with the 5-m HPC in Hole 588A, despite the high intensities. Directional scatter is high and there is a marked negative (normal) bias to inclinations, suggesting viscous overprinting in the present-day field. No polarity interpretation was possible for Hole 588A.

The increase in intensity at the top of the section is presumably due to the reasons discussed in the Introduction. The origin of higher intensities prior to the late Miocene is not clear. Two possibilities are (1) enhanced input of terrigenous material, and (2) inhibition of the reducing conditions which are probably responsible for the falloff in intensity as a function of depth at the top of the section.

SEDIMENTATION RATES

Sedimentation rates were calculated from calcareous nannoplankton zonal boundaries for the four holes drilled at Site 588. Hole 588B (Fig. 11C) duplicated the results from Hole 588. However, since zonal boundaries in Hole 588B were based only on core-catcher samples, sedimentation rates for this particular hole are less reliable than those for the other three holes.

Ages of nannoplankton boundaries used to determine sedimentation rates are the same as those used during Leg 59 (Martini, 1981) with some minor improvements. Middle Eocene sedimentation rates could not be calculated in the calcareous–siliceous sediments, because the section (Cores 588C-17 and 588C-18) was too short and no zonal boundaries were detected.

In the late Oligocene to early Miocene interval (Hole 588C, nannoplankton Zones NN2 top to NN24 top), the sedimentation rate is 20.6 m/m.y. in calcareous sediments, based on four boundary datums (Fig. 12D). The mean sedimentation rate in the early Miocene (Hole 588A, nannoplankton Zones NN2 top to NN7 top), based on six boundary datums, shows a slight decrease to 14.4 m/m.y., also in calcareous sediments (Fig. 11B). The sedimentation rate in the middle Miocene to early Pliocene interval (Hole 588, nannoplankton Zones NN7 top to NN13 top) is constant at 17.4 m/m.y., based on six datum levels (Fig. 11A). In the late Pliocene (Hole 588, nannoplankton Zones NN13 top to NN18 top) the sedimentation rate increases rather abruptly to 29.5 m/m.y., and drops off to only 12.2 m/m.y. in the Quaternary interval (Hole 588, above nannoplankton Zone NN18 top), both in calcareous sediments. The two latter sedimentation rates are based on eight datum levels (Fig. 11A). The comparatively low sedimentation rate in the Quaternary may be unreliable, and may have resulted from drilling disturbance in the uppermost layers or from winnowing of finer sediments.

SUMMARY AND CONCLUSIONS

Site 588 was drilled at the same location as Site 208 in order to obtain a high-quality, continuously cored sequence through the late Paleogene and Neogene. Previous investigations have demonstrated that the planktonic foraminiferal assemblages at this latitude are made up of both tropical and temperate elements. At the present time, Site 588 is located in the warm subtropical water mass which lies between the true tropical water masses to the north and transitional water masses to the south. However, Site 588 experienced 5–10° of northerly movement during the Neogene in association with movements of the Indian Plate (Sclater et al., in press). During the early Miocene, Site 588 was located at about 36°S in the present-day temperate area and within the zone of westerly winds. This northward movement from higher to lower latitudes must have had a major effect upon the biogeography of the planktonic microfossil assemblages.

Site 588 consists of four holes (Fig. 12): Hole 588, cored continuously with the HPC from 0–236.0 m sub-bottom; Hole 588A, cored continuously with the HPC from 236.0–344.4 m; Hole 588B, cored continuously with the HPC from 0–277.4 m; and Hole 588C cored continuously with the rotary drill from 305.7–488.1 m sub-bottom.

The HPC sequence through carbonate sediments is a record penetration of 315 m, extending from the Quaternary to the late early Miocene at 17 m.y. (Zone NN3 or *Globorotalia miozea* Zone). The overlapping hydraulic piston cores effectively provide 100% recovery of this sequence (Fig. 12). There is particularly good core quality in the Miocene, much less so in the Pliocene, and especially poor quality in the Quaternary, which is soupy. The carbonate fossil sequence is exquisite through the

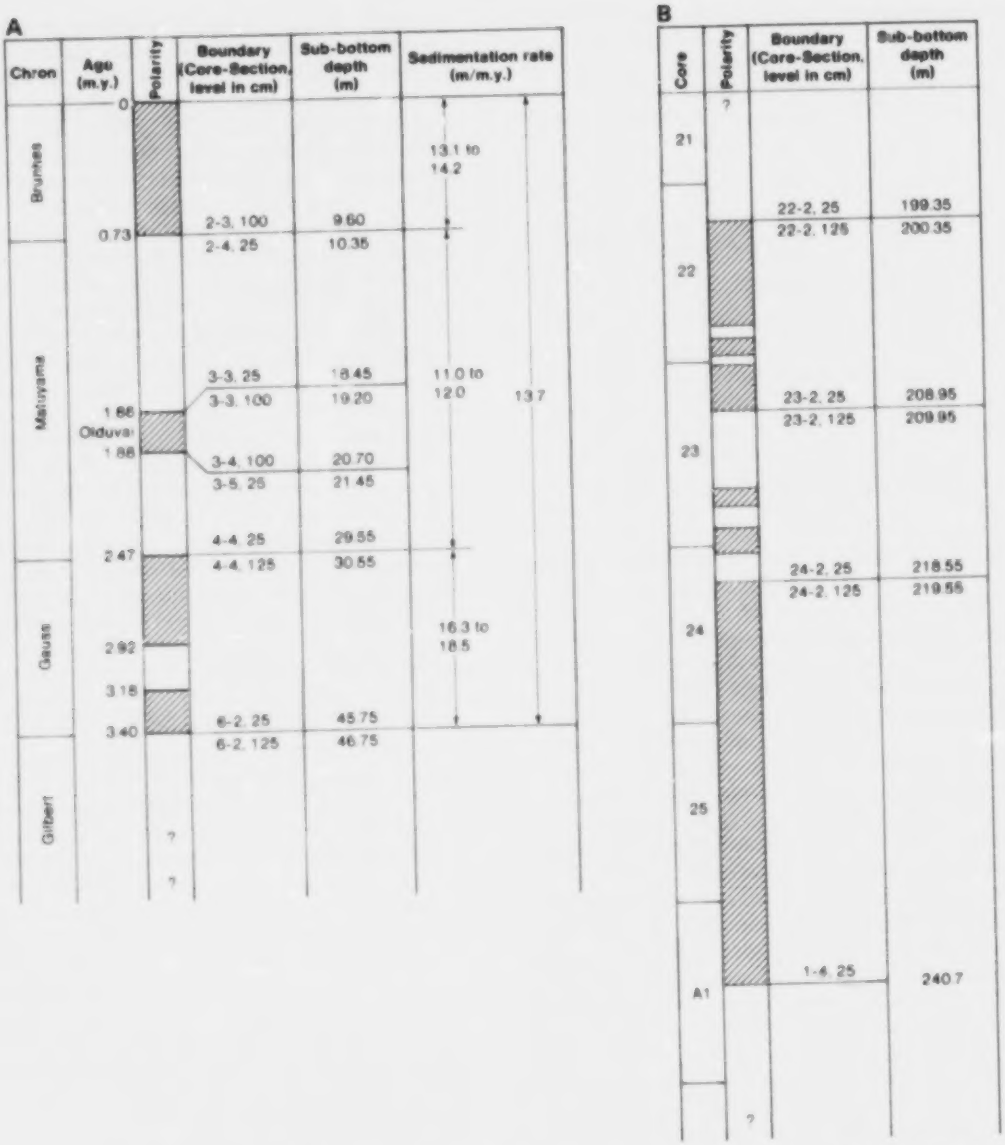

A
Chron
Age (m.y.)
Polarity
Boundary (Core-Section, level in cm)
Sub-bottom depth (m)
Sedimentation rate (m/m.y.)
Brunhes
Matuyama
Gauss
Gilbert
0
0.73
1.66
Olduvai
1.88
2.47
2.92
3.18
3.40
2-3, 100
2-4, 25
3-3, 25
3-3, 100
3-4, 100
3-5, 25
4-4, 25
4-4, 125
6-2, 25
6-2, 125
9.60
10.35
18.45
19.20
20.70
21.45
29.55
30.55
45.75
46.75
13.1 to 14.2
11.0 to 12.0
13.7
16.3 to 18.5
?
?
B
Core
Polarity
Boundary (Core-Section, level in cm)
Sub-bottom depth (m)
21
22
23
24
25
A1
?
22-2, 25
22-2, 125
23-2, 25
23-2, 125
24-2, 25
24-2, 125
1-4, 25
199.35
200.35
208.95
209.95
218.55
219.55
240.7
?

Figure 10. A. Magnetic polarity boundaries for the upper part of Hole 588. B. Polarity zonations at the bottom of Hole 588 and the top of 588A. Shaded zones are normal polarity.

Neogene but less so in the Oligocene. The foraminiferal and calcareous nannofossil zonal sequences are complete (Fig. 12), suggesting that there are no hiatuses above the upper Oligocene (NP24). A paleomagnetic polarity stratigraphy has been identified down to the upper part of the Gilbert Chron (about 3.5 m.y.).

Two sedimentary units are distinguished (Fig. 12), the upper one divided into three subunits. Subunit IA is a foraminifer-bearing nannofossil size to a nannofossil-bearing foraminiferal ooze in an oxidized and winnowed environment. Subunit IB, comprising much of the sediment column at Site 588, is largely a foraminifer-bearing nannofossil ooze, distinguished from Subunit IC by its softness. Subunit IC grades from soft ooze at its top to firm ooze at about 150 to 180 m (Holes 588 and 588B, respectively) to chalk at about 215 to 260 m (Holes 588 and 588B, respectively).

At the bottom of Site 588 (Hole 588C) is Unit II which is separated from overlying Unit IC by the regional unconformity that separates middle or late Eocene from late or middle Oligocene sediments. At Site 588 the unconformity separates sediments of middle Eocene (NP15-16) from late Oligocene (NP24) age.

The middle Eocene sediments consist of siliceous foraminifer-bearing nannofossil chalks and foraminifer-bearing cherts. Less than 1 m of Unit II was recovered before the site was terminated. This lithostratigraphic unit is characterized by the presence of siliceous sponge spicules, diatoms, and diagenetic chert, and coincides with Unit 2 of DSDP Site 208 (Burns, Andrews, et al., 1973).

Textbook examples of microfaults and slickensides occur in three upper lower Miocene cores in a zone where ooze grades into chalks. Surfaces are occasionally mineralized by iron sulfide and possibly rhodochrosite.

There are many thin volcanic ash layers through the Miocene sequence, occurring as singlets, doublets, or triplets and with groups exhibiting quasi-regular perodicities in some intervals. Most are completely undisturbed by bioturbation, which is unusually limited in this site and is an ineffective agent of sediment homogenization. Nevertheless, excellent examples of Zoophycos and Chondrites burrows occur throughout this sequence, as well as relatively sparse larger circular or ovoid (0.5–3.0 cm across) burrow sections and mottles.

Iron sulfides are persistent through the section and have a close association with volcanic ash layers. Drilling terminated in middle Eocene siliceous-rich chalks and cherts.

The uncorrected rates of sedimentation are as follows: lower Oligocene–early Miocene, 20.6 m/m.y.; early Miocene, 14.4; middle Miocene–early Pliocene, 17.4, lower Pliocene, 29.5; Quaternary, 12.2 m/m.y.

In general, the diversity of the benthic faunas and their abundance decrease down the section. Changes in the benthic foraminiferal assemblages provide useful information about changes in intermediate water masses during the Neogene. Elimination of typical Eocene–Oligocene benthic forms occurred in the late early Miocene. During the early late Miocene there was an influx of several species of deeper-water origin. During the Pliocene there was an upward disappearance of several important benthic species and a large number of species disappeared during the late Pliocene, at about 3 m.y.

REFERENCES

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931–958.

________, 1977. Deep Sea Drilling Project procedures for shear strength measurement of clayey sediment using modified Wykeham Farrance laboratory vane apparatus. *In* Barker, P. F., Dalziel, I. W. D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 1059–1068.

Burns, R. E., Andrews, J. E., et al., 1973. *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office).

Kennett, J. P., 1973. Middle and late Cenozoic planktonic foraminiferal biostratigraphy of the southwest Pacific—DSDP Leg 21. *In* Burns, R. E., Andrews, J.E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 575–640.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports, Scripps Institution of Oceanography, La Jolla, California.

Martini, E., 1981. Oligocene to recent calcareous nannoplankton from the Philippine Sea, Deep Sea Drilling Project Leg 59. *In* Kroenke, L., Scott, R., et al. (Eds.), *Init. Repts. DSDP*, 59: Washington (U.S. Govt. Printing Office), 547–565.

Sclater, J. G., Meinke, L., Bennett, A., and Murphy, C., in press. The depth of the ocean through the Neogene. *In* Kennett, J. P. (Ed.), *The Miocene Ocean: Paleoceanography and Biogeography*. Geol. Soc. Am. Mem. 163.

Srinivasan, M. S., and Kennett, J. P., 1981a. A review of Neogene planktonic foraminiferal biostratigraphy: Applications in the equatorial and South Pacific. *In* Warme, J. E., Douglas, R. G., Winterer, E. L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress*. Soc. Econ. Paleont. Mineral., Spec. Pub., 32:395–432.

________, 1981b. Neogene planktonic foraminiferal biostratigraphy and evolution: equatorial to subantarctic, South Pacific. *Mar. Micropaleontol.*, 6:499–533.

________, 1983. The Oligocene/Miocene boundary in the South Pacific. *Geol. Soc. Am. Bull.*, 94:798–812.

Willcox, J. B., Symonds, P. A., Hinz, K., and Bennett, D., 1980. Lord Howe Rise, Tasman Sea—preliminary geophysical results and petroleum prospects. *B.M.R. J. Aust. Geol. Geophys.*, 5:225–236.

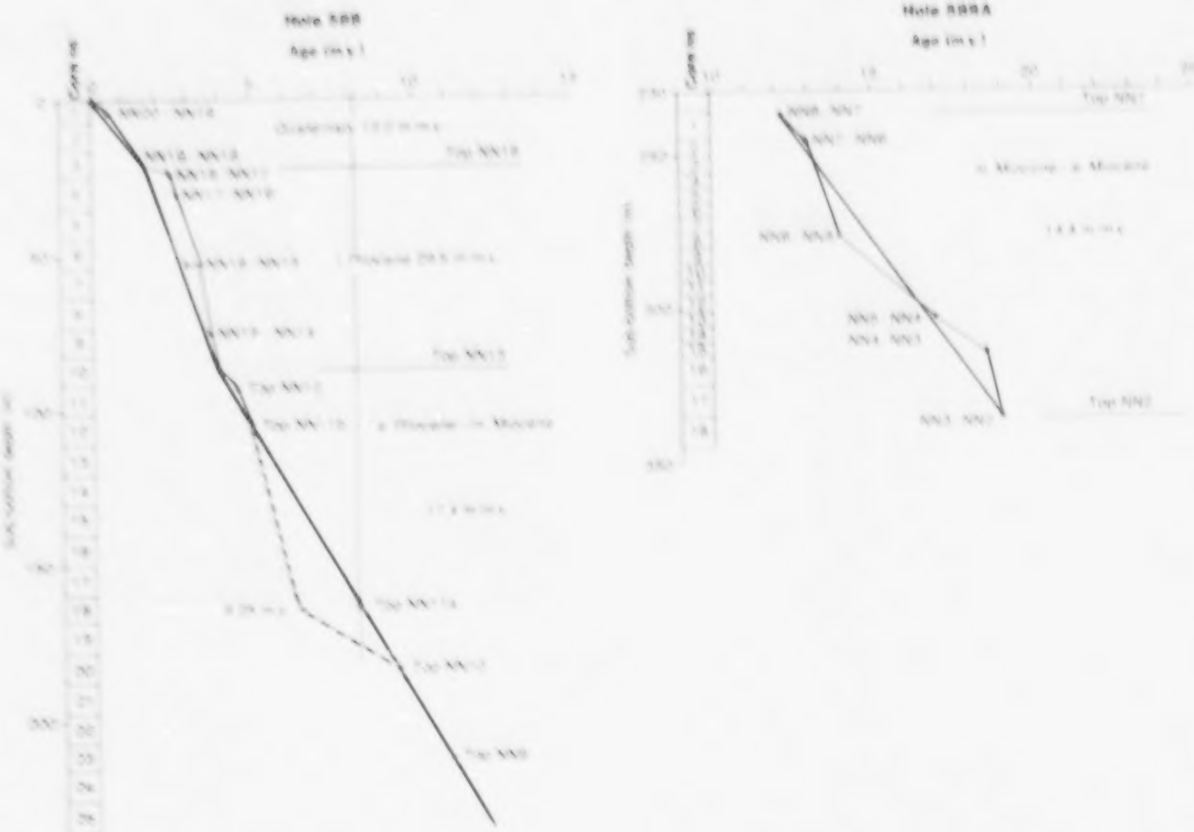


Figure 11. Sedimentation rates at Site 588.

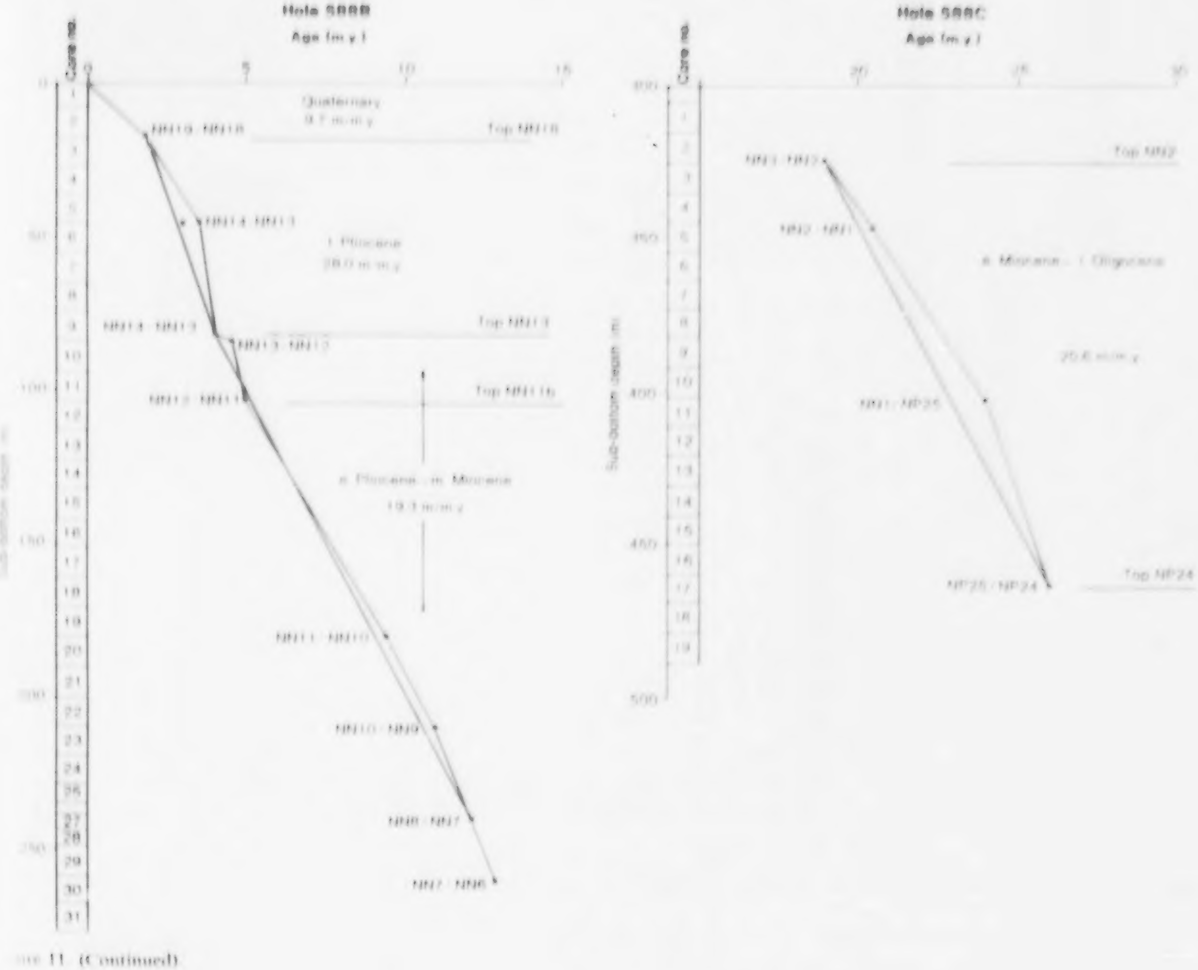


Figure 11. (Continued).

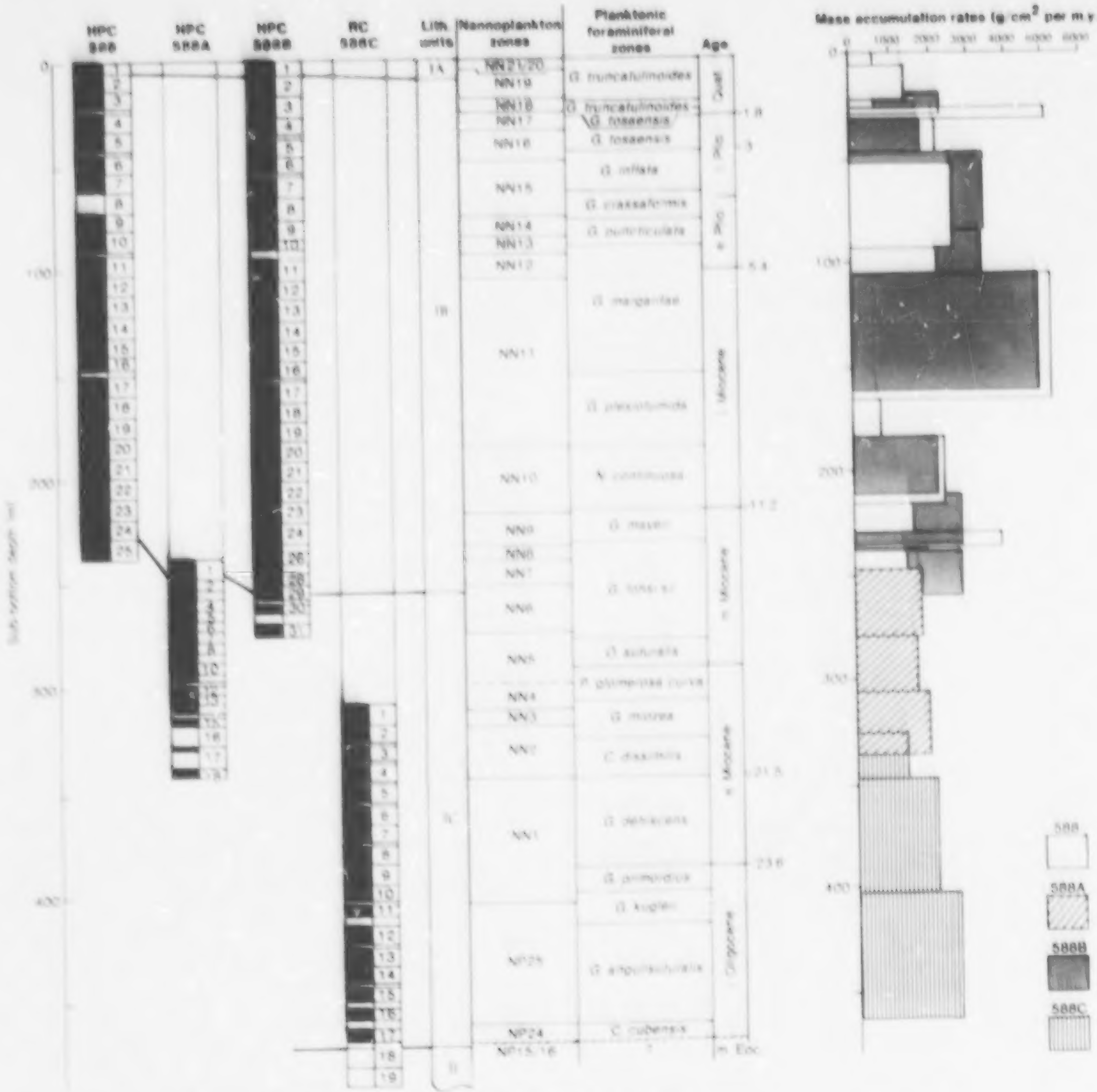
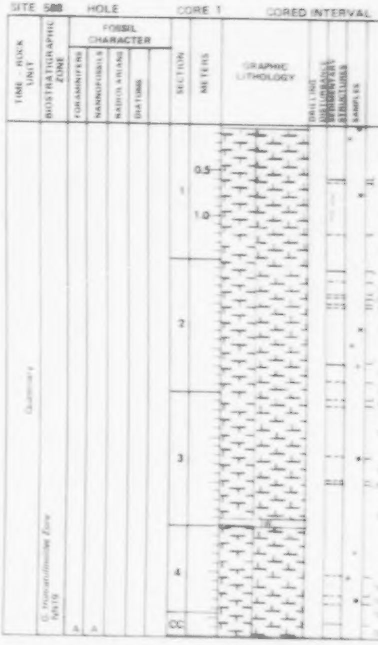


Figure 12. Summary biostratigraphy, lithology, and mass accumulation rates at Site 588.

SITE 588 HOLE CORE 1 CORED INTERVAL 0.0–5.6 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides Zone
NN19
A
A
0.5
1.0
1
2
3
4
CC
10YR 7/4
10YR 7/2
10YR 7/4
10YR 8/2
10YR 7/4
10YR 8/2
N8
N8
10YR 8/2
10YR 7/4
10YR 8/2
10YR 8/4
10YR 8/2
10YR 8/4
N7
10YR 8/2
10YR 8/2
10YR 8/2
10YR 8/2
10YR 8/4

LITHOLOGIC DESCRIPTION

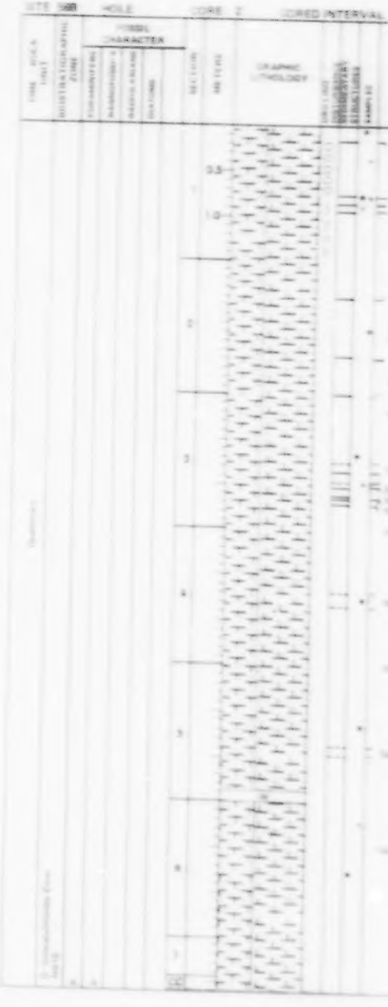
FORAMINIFER-BEARING NANNOFOSSIL OOZE TO FORAMINIFER NANNOFOSSIL OOZE, soft, [illegible], oxidized, various shades of orange becoming paler orange downcore.

Some burrowing, bedding, and [illegible].

SMEAR SLIDE SUMMARY:

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Composition:					
Quartz	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Heavy minerals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foraminifers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sponge spicules	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SITE 588 HOLE CORE 2 CORED INTERVAL 5.6–15.2 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides Zone
NN19
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

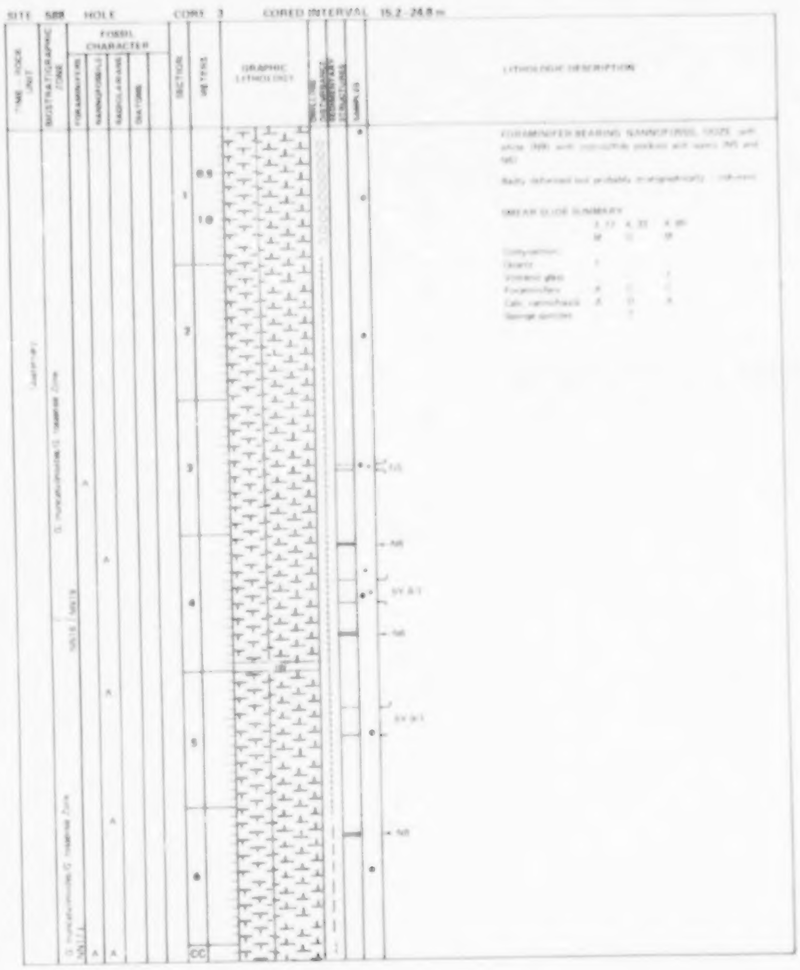
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9), with the subordinate lithologies as noted:

1. [illegible]
2. [illegible] bottom and top contacts.
3. [illegible] orange [illegible], oxidized, [illegible].
4. [illegible], very light gray (N8), [illegible].
5. [illegible] lithology with subtle color variations due to:
   a. [illegible]
   b. [illegible]

SMEAR SLIDE SUMMARY:

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Composition:					
Quartz	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Volcanic glass	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Carbonate unspec.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foraminifers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sponge spicules	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

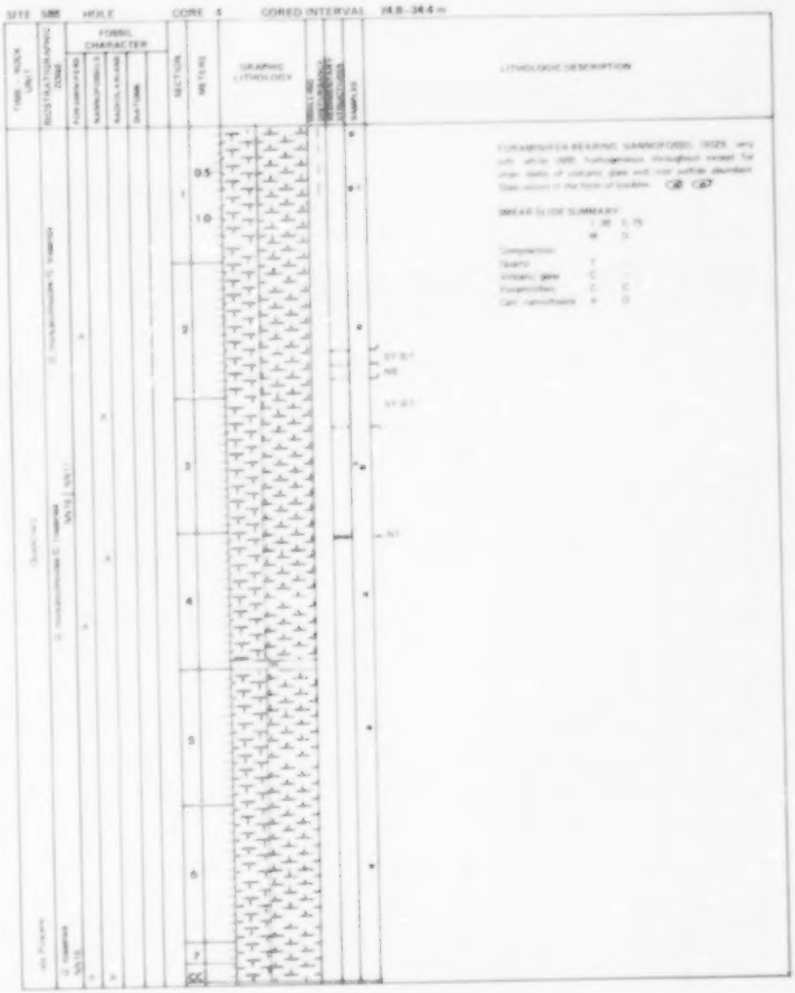

SITE 588 HOLE CORE 3 CORED INTERVAL 15.2–24.8 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
G. truncatulinoides/G. tosaensis Zone
NN20 | NN19
A
0.5
1.0
1
2
3
4
5
6
CC
N5
N6
5Y 8/1
N6

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) with iron-sulfide pockets and specs (N5 and N6).

Badly deformed but probably stratigraphically coherent.

SMEAR SLIDE SUMMARY

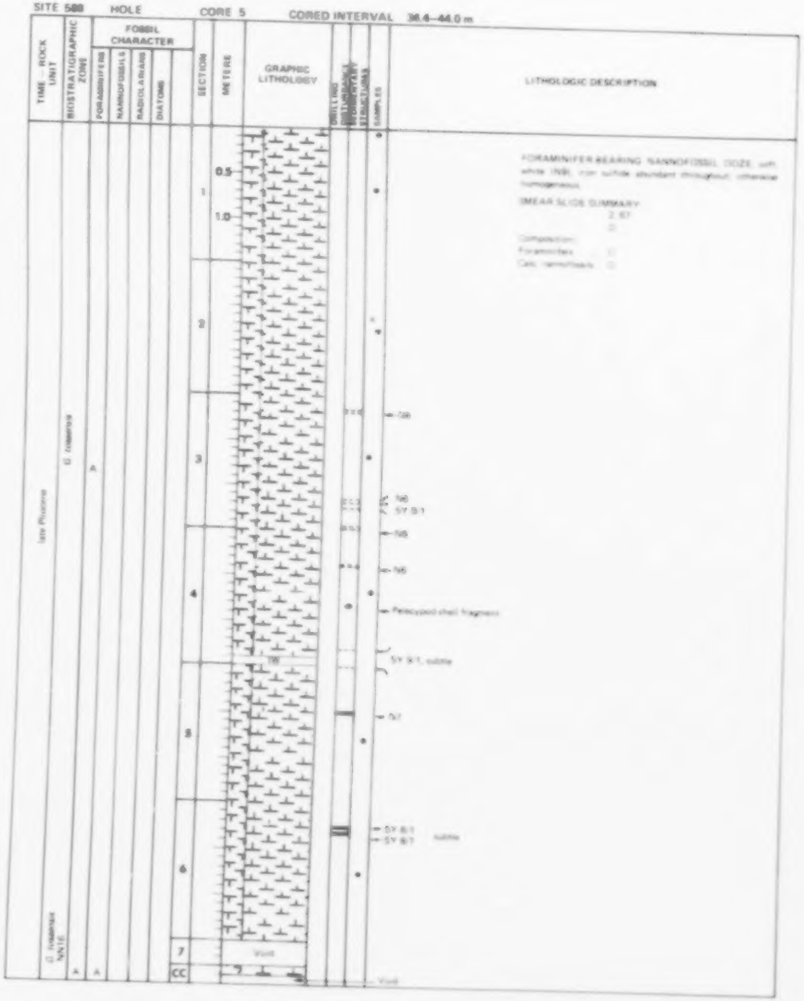
	3, 17	4, 33	4, 89
	M	D	M
Composition:			
Quartz	T		
Volcanic glass			T
Foraminifers	A	C	C
Calc. nannofossils	A	D	A
Sponge spicules		T	


SITE 588 HOLE CORE 4 CORED INTERVAL 24.8–34.4 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19 | NN17
NN18
G. tosaensis
A
0.5
1.0
1
2
3
4
5
6
7
CC
5Y 8/1
N8
5Y 8/1
N7

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very soft, white (N9), homogeneous throughout except for minor blebs of volcanic glass and iron sulfide abundant. Glass occurs in the form of bubbles.

SMEAR SLIDE SUMMARY

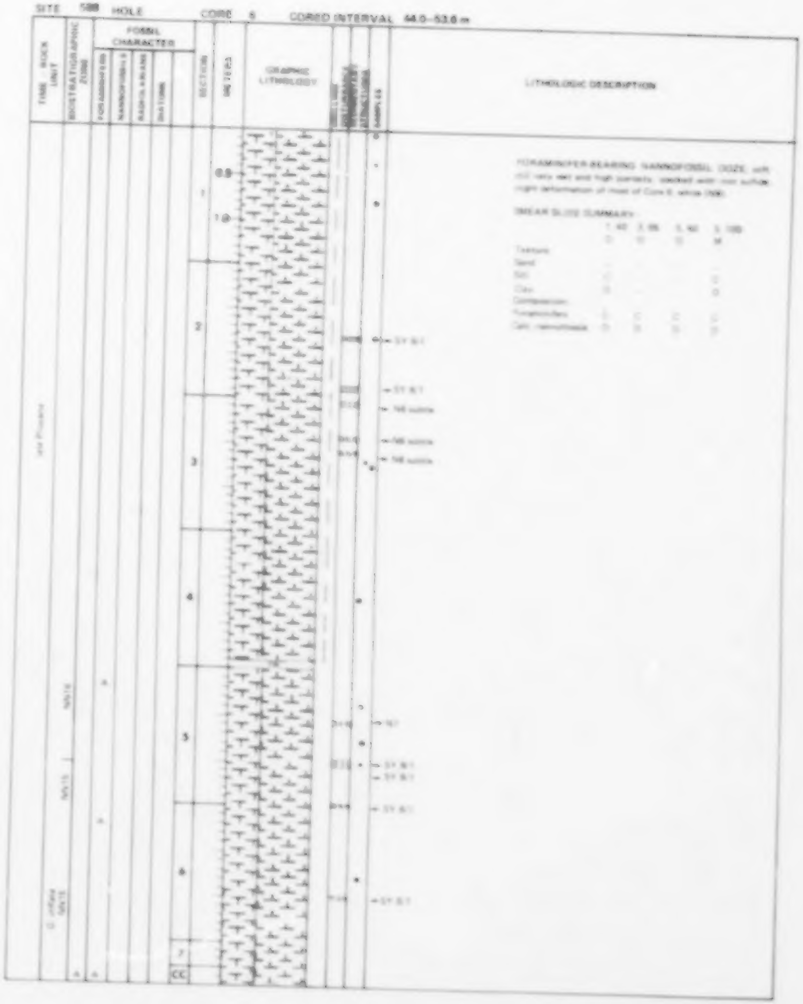
	1, 38	5, 75
	M	D
Composition:		
Quartz	T	
Volcanic glass	C	
Foraminifers	C	C
Calc. nannofossils	A	D


SITE 588 HOLE CORE 5 CORED INTERVAL 38.4–44.0 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
G. inflata
A
G. inflata NN16
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
N8
5Y 8/1
N8
N8
Pelecypod shell fragment
5Y 8/1, subtle
N7
5Y 8/1
5Y 8/1
subtle
Void

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9), iron sulfide abundant throughout; otherwise homogeneous.

SMEAR SLIDE SUMMARY

	2, 67
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

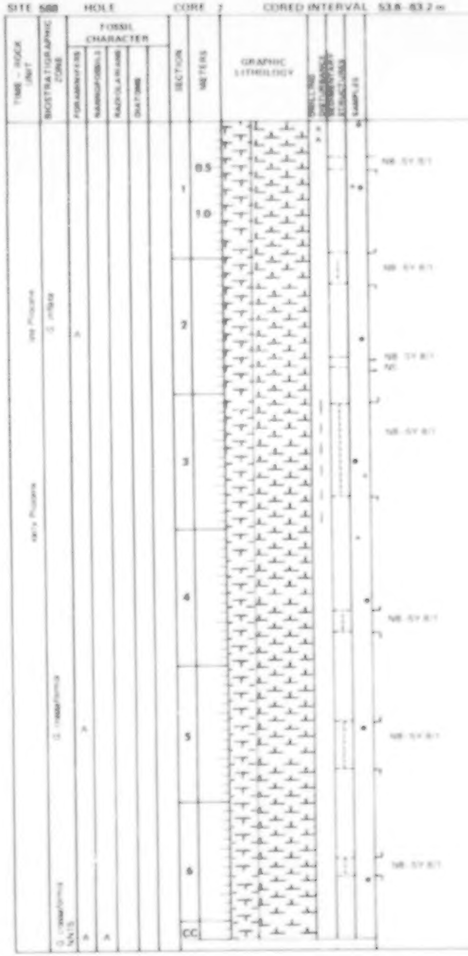

SITE 588 HOLE CORE 6 CORED INTERVAL 44.0–53.6 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
NN16
A
NN15
A
G. inflata NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5Y 8/1
5Y 8/1
N8 subtle
N8 subtle
N8 subtle
N7
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very wet and high porosity, speckled with iron sulfide; slight deformation of most of Core 6, white (N9).

SMEAR SLIDE SUMMARY

	1, 40	2, 95	3, 40	5, 100
	D	D	D	M
Texture:				
Sand	–	–	–	–
Silt	C	–	–	C
Clay	D	–	–	D
Composition:				
Foraminifers	C	C	C	C
Calc. nannofossils	D	D	D	D

SITE 588 HOLE CORE 7 CORED INTERVAL 53.8–63.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
early Pliocene
G. inflata
G. crassaformis
NN15
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N5
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, with white (N9) to very light gray (N8).

Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

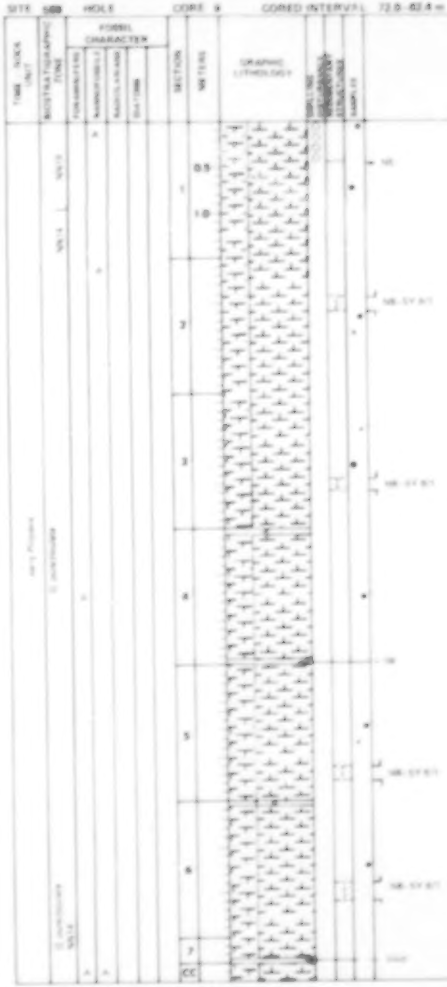
Medium gray (N5) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY:

	1, 80	2, 96	4, 15
	D	M	M
Texture:			
Sand			
Silt	C	C	C
Clay	D	D	D
Composition:			
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

Note: Core 8 (63.2–72.8 m): no recovery.

SITE 588 HOLE CORE 9 CORED INTERVAL 72.8–82.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
NN14
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N5
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
Void

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, with white (N9) to very light gray (N8).

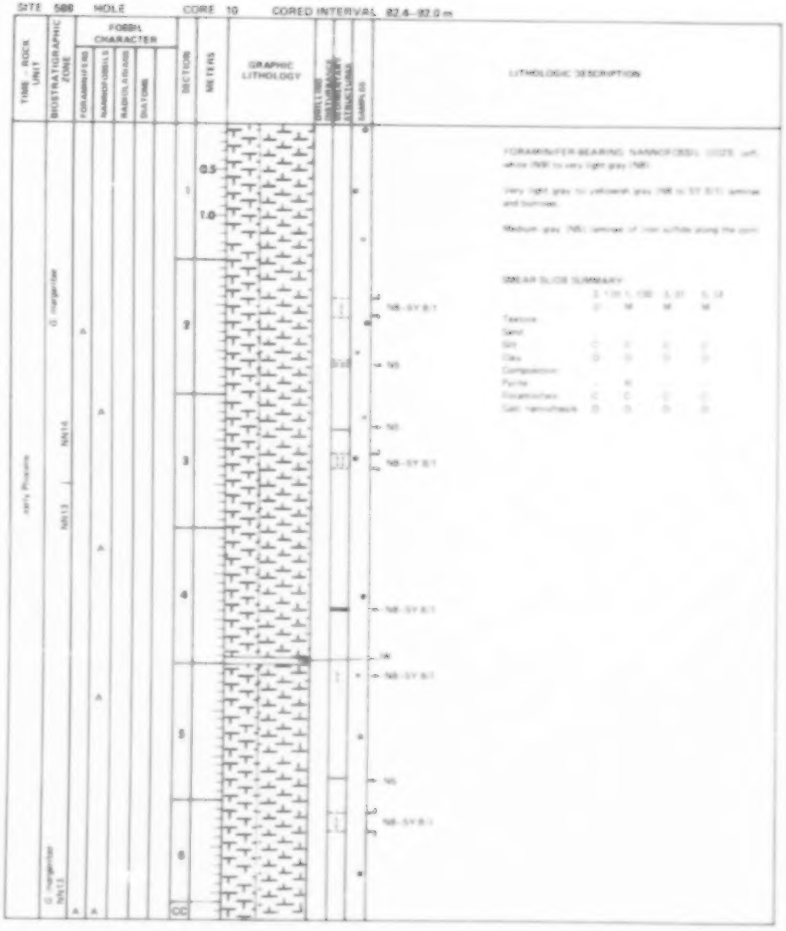
Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

Medium gray (N5) laminae along the core (iron sulfide).

* Artificial gas combustion.

SMEAR SLIDE SUMMARY:

	1, 42	2, 92	5, 79
	D	M	M
Texture:			
Sand			
Silt	C	C	C
Clay	D	D	A
Composition:			
Pyrite	T		
Foraminifers	C	C	A
Calc. nannofossils	D	D	D
Other		T	T


SITE 588 HOLE
CORE 10
CORED INTERVAL 82.4–92.0 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. margaritae
NN14
NN13
G. margaritae
NN13
A
A
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8–5Y 8/1
N5
N5
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N5
N8–5Y 8/1

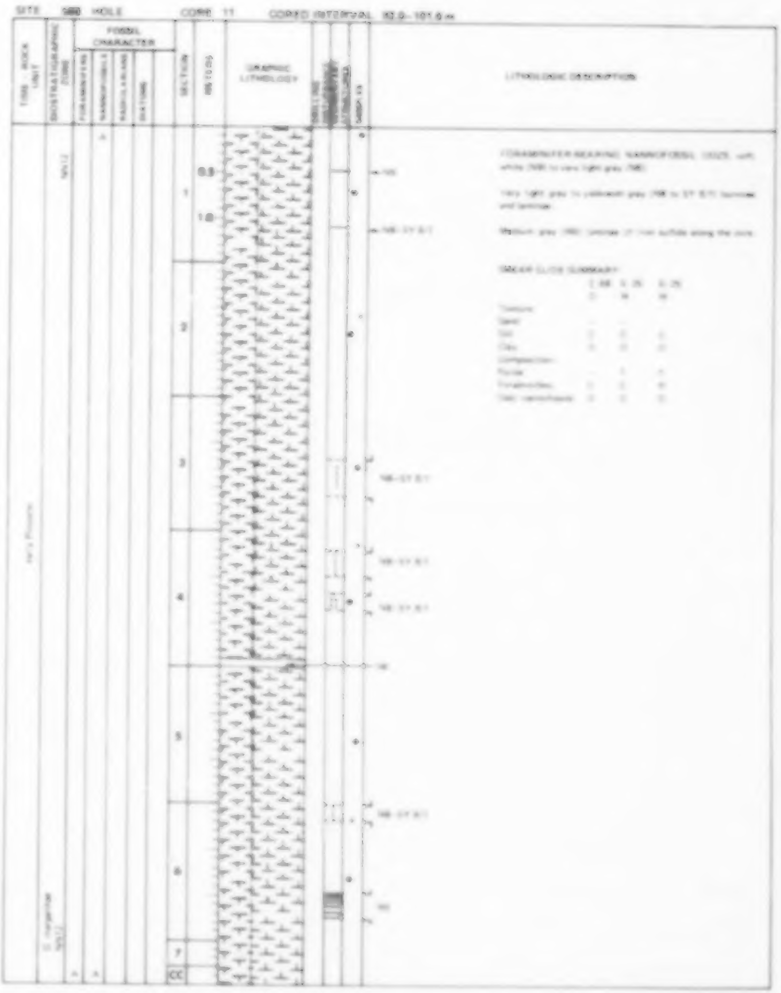
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

Very light gray to yellowish gray (N8 to 5Y 8/1) laminae and burrows.

Medium gray (N5) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY

	2, 135	1, 130	3, 31	5, 12
	D	M	M	M
Texture:				
Sand				
Silt	C	T	T	T
Clay	D	D	D	D
Composition:				
Pyrite	—	R	—	—
Foraminifers	C	C	C	C
Calc. nannofossils	D	D	D	D


SITE 588 HOLE
CORE 11
CORED INTERVAL 92.0–101.6 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN12
G. margaritae
NN12
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N5
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N5

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

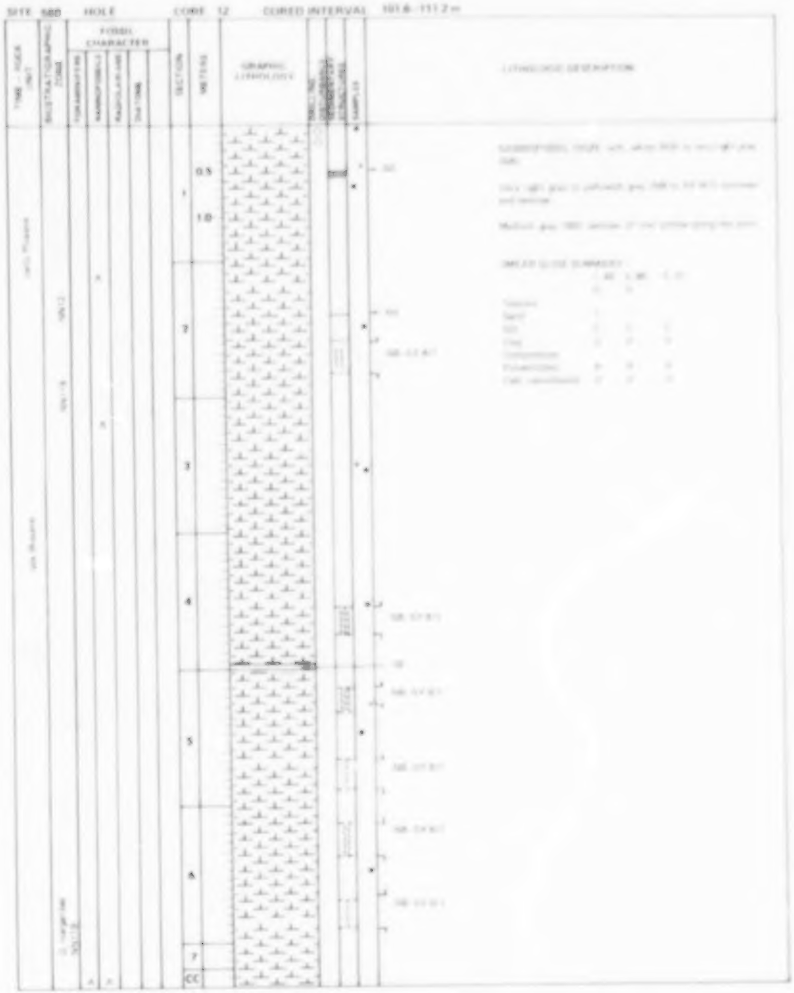
Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

Medium gray (N5) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY

	1, 68	3, 25	6, 25
	D	M	M
Texture:			
Sand	—	—	
Silt	C	C	C
Clay	C	D	D
Composition:			
Pyrite	—	T	R
Foraminifers	C	C	R
Calc. nannofossils	D	D	D

SITE 588 HOLE CORE 12 CORED INTERVAL 101.6–111.2 m

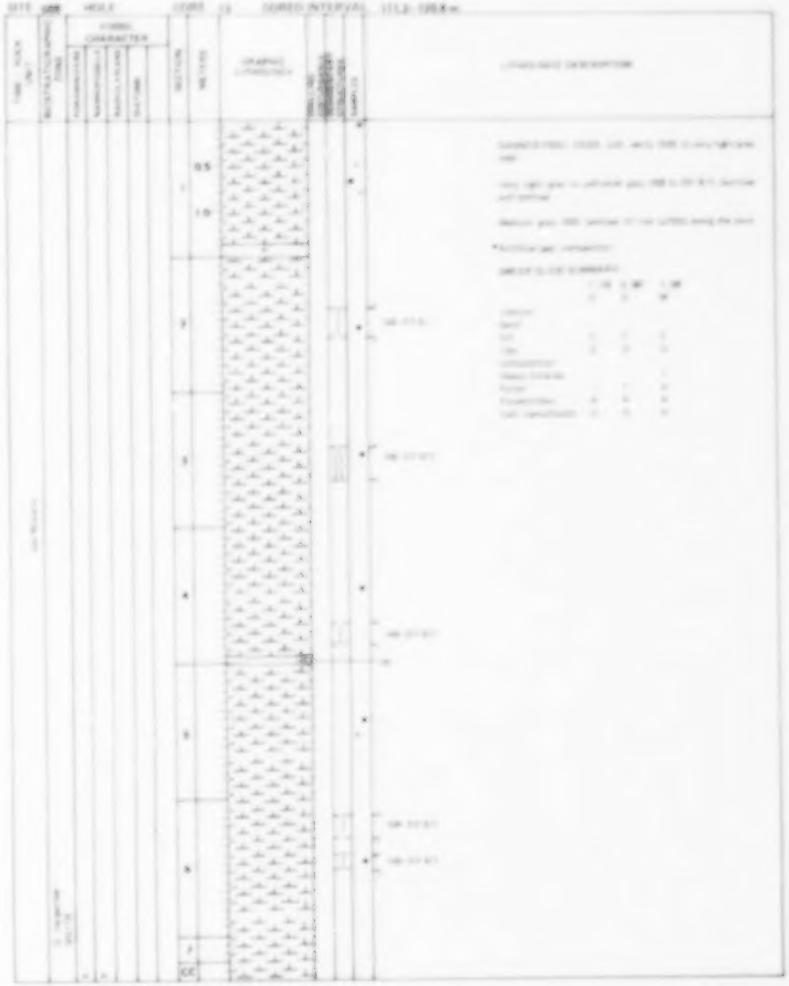

TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
4
5
6
7
CC

[illegible]

SMEAR SLIDE SUMMARY

Texture:
Sand
Silt
Clay
Composition:
Foraminifers
Calc. nannofossils

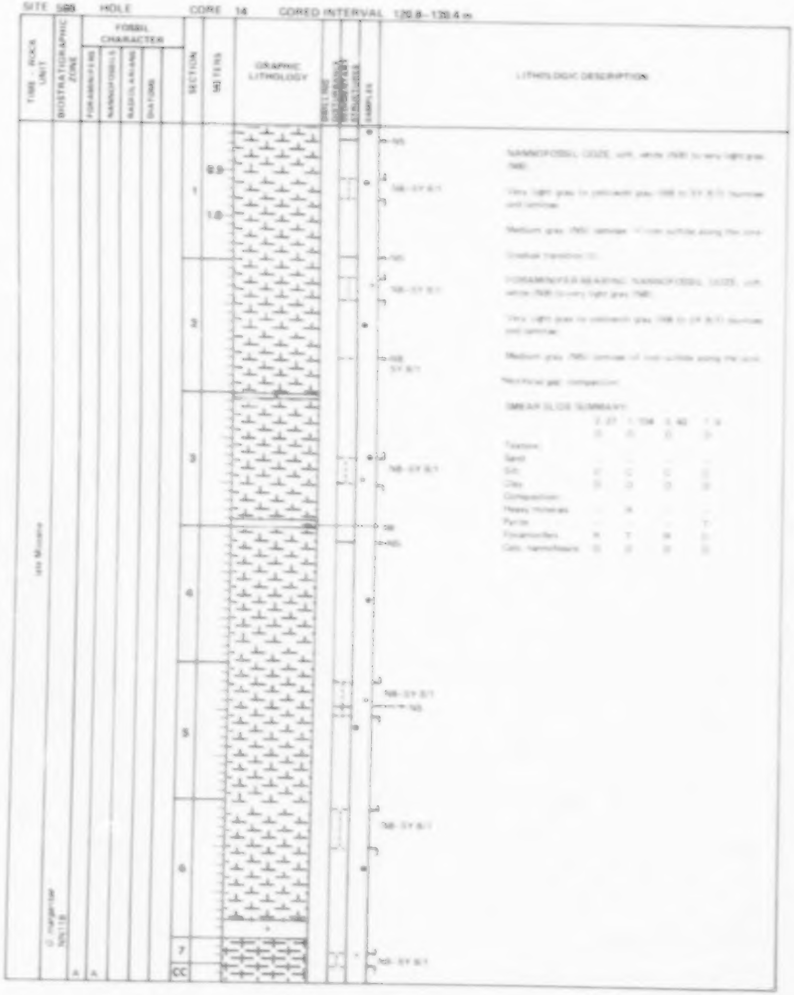
SITE 588 HOLE CORE 13 CORED INTERVAL 111.2–120.8 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
4
5
6
7
CC

[illegible]

SMEAR SLIDE SUMMARY

Texture:
Sand
Silt
Clay
Composition:
Foraminifers
Calc. nannofossils


SITE 588 HOLE CORE 14 CORED INTERVAL 120.8–130.4 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. margaritae
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N9
N8-5Y 8/1
N5
N8-5Y 8/1
N8
5Y 8/1
N8-5Y 8/1
N9
N5
N8-5Y 8/1
N5
N8-5Y 8/1
N8-5Y 8/1

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

Medium gray (N5) laminae of iron sulfide along the core.

Gradual transition to:

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

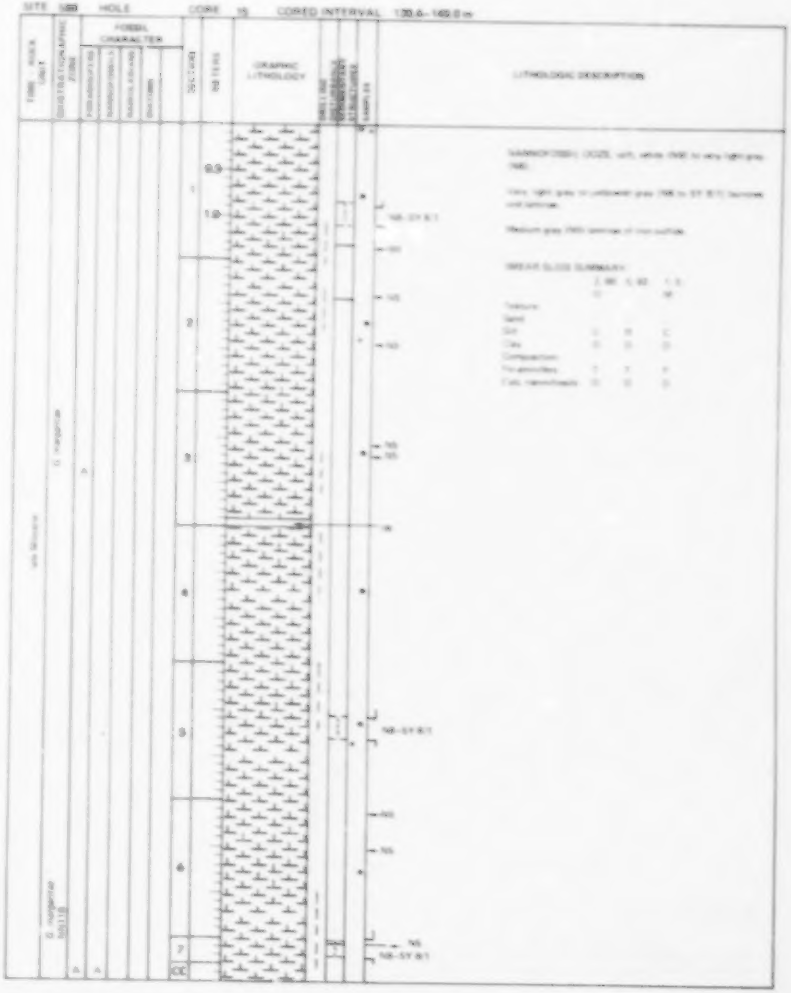
Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

Medium gray (N5) laminae of iron sulfide along the core.

*Vertical gas compaction.

SMEAR SLIDE SUMMARY:

	2, 27	1, 104	3, 40	7, 9
	D	D	D	D
Texture:				
Sand	—	—	—	—
Silt	C	C	C	C
Clay	D	D	D	D
Composition:				
Heavy minerals	—	R	—	—
Pyrite	—	—	—	T
Foraminifers	R	T	R	C
Calc. nannofossils	D	D	D	D


SITE 588 HOLE CORE 15 CORED INTERVAL 130.4–140.0 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. margaritae
G. margaritae
NN11B
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8-5Y 8/1
N9
N5
N5
N5
N5
N8-5Y 8/1
N9
N5
N5
N8-5Y 8/1

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

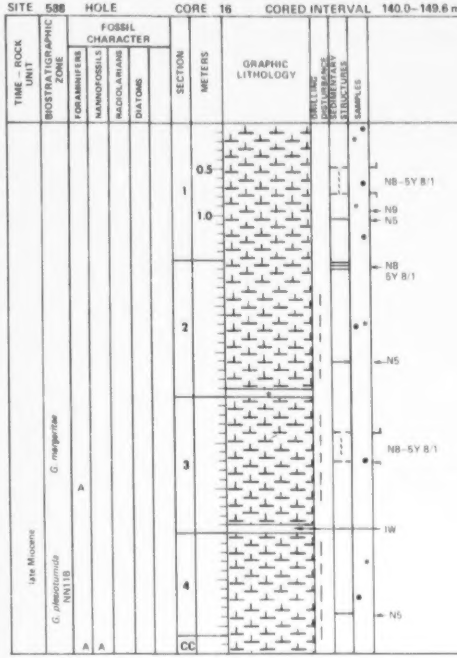
Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae.

Medium gray (N5) laminae of iron sulfide.

SMEAR SLIDE SUMMARY:

	2, 90	5, 82	7, 5
	D		M
Texture:			
Sand	—	—	—
Silt	C	R	C
Clay	D	D	D
Composition:			
Foraminifers	T	T	F
Calc. nannofossils	D	D	D

SITE 588 HOLE CORE 16 CORED INTERVAL 140.0–149.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. margaritae
G. pleiotumida NN11B
A
A A
1
2
3
4
CC
0.5
1.0
N8–5Y 8/1
N9
N5
N8 5Y 8/1
N5
N8–5Y 8/1
IW
N5

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, firm, white (N9) to very light gray (N8)

Very light gray to yellowish gray (N8 to 5Y 8/1) burrows and laminae

Medium gray (N5) laminae of iron sulfide along the core.

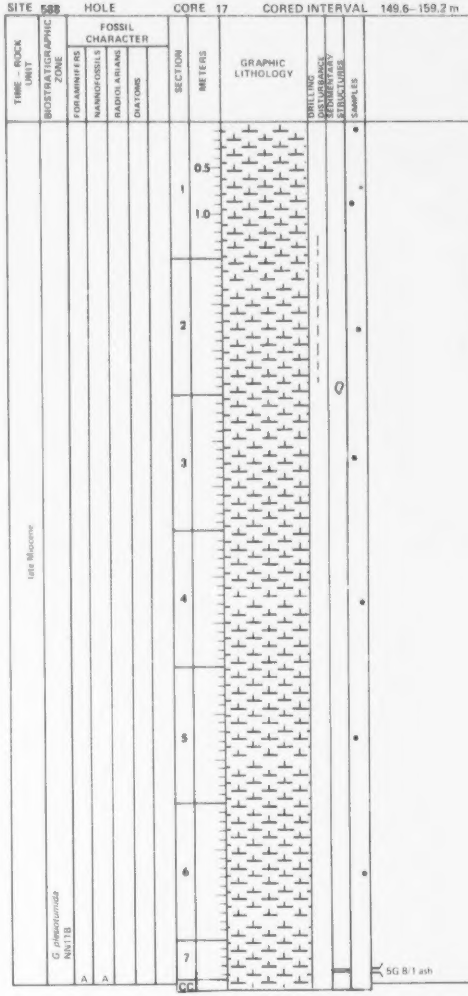
Grayish green to pale yellowish green (10GY 5/2 to 10GY 7/2) nodule at 21 cm in Section 1.

*Artificial gap: compaction

SMEAR SLIDE SUMMARY

	2, 70	4, 29	1, 22	1, 88
	D	D	M	M
Texture:				
Sand	–	–	C	–
Silt	R	R	C	C
Clay	D	D	D	D
Composition:				
Pyrite	T	–	–	C
Foraminifers	T	R	C	C
Calc. nannofossils	D	D	D	D

SITE 588 HOLE CORE 17 CORED INTERVAL 149.6–159.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. pleiotumida NN11B
A A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 8/1 ash

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, firm, white (N9) with abundant iron sulfide blebs throughout, yellowish gray (5Y 8/1) burrows and laminations also abundant.

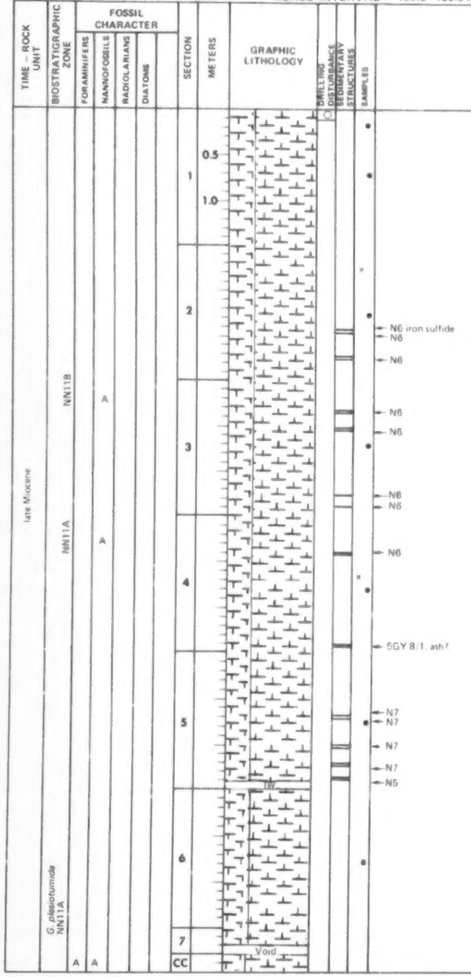
Massive pyrite nodule at base of Section 2. Several hard iron sulfide dark gray (N3) burrow fills in Section 3.

SMEAR SLIDE SUMMARY

	1, 77
	D
Texture:	
Sand	–
Silt	C
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

READEX FICHE best copy available

SITE 588 HOLE CORE 18 CORED INTERVAL 159.2–168.8 m



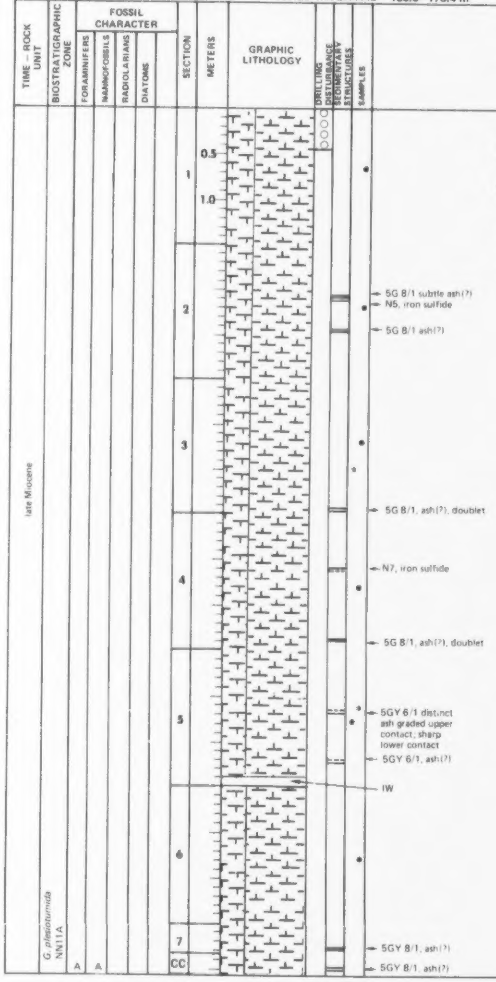
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, moderately soft, but dewatered; white (N9); abundant blebs of iron sulfide (N6) and abundant yellowish gray burrows (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 35	4, 71
	D	D
Composition:		
Quartz	–	T
Feldspar	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 588 HOLE CORE 19 CORED INTERVAL 168.8–178.4 m

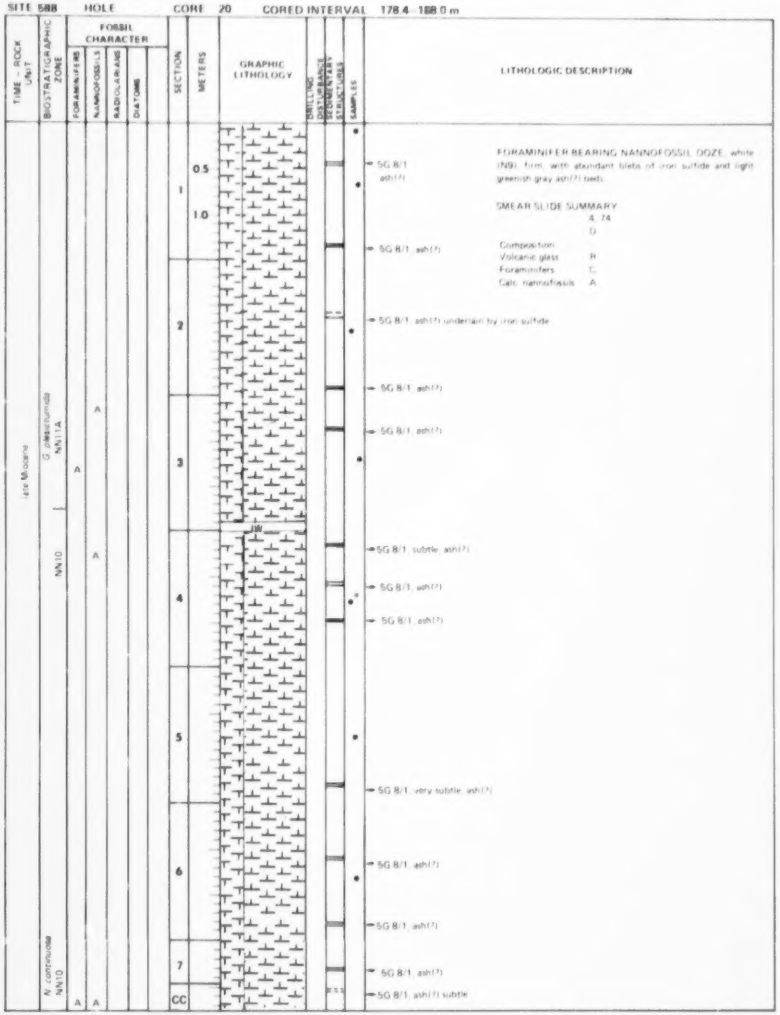


LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9), firm, iron sulfide and burrows abundant; picking up some ash(?) layers in Section 2.

SMEAR SLIDE SUMMARY:

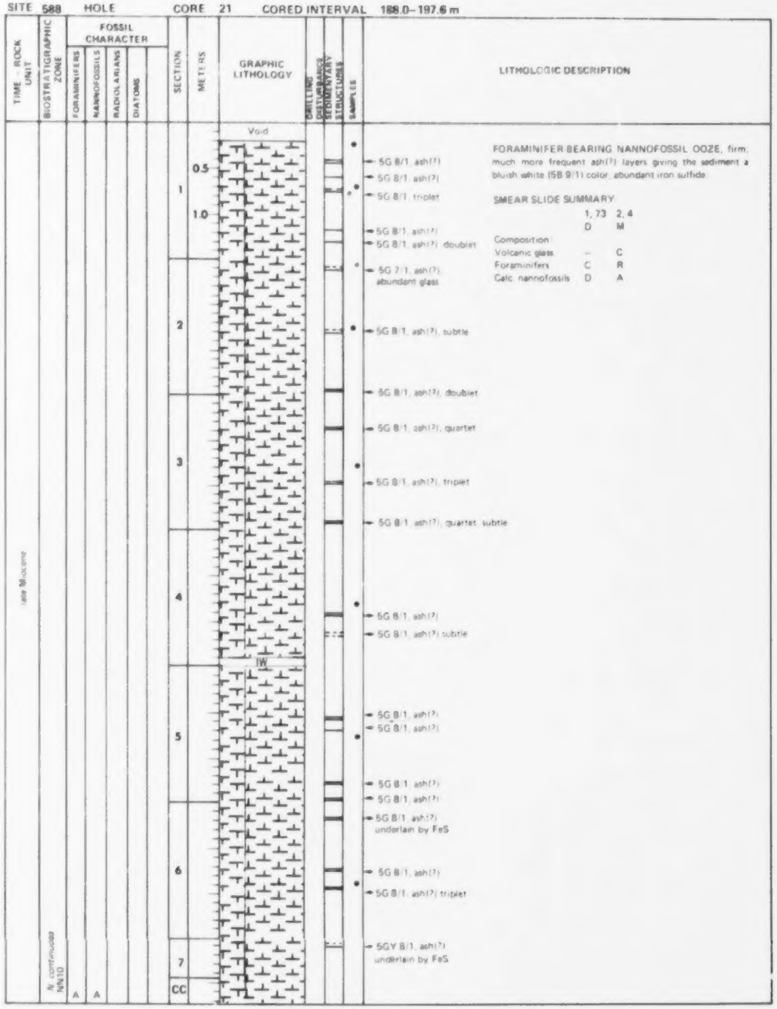
	3, 101	5, 63
	D	M
Composition:		
Volcanic glass	–	C
Foraminifers	C	C
Calc. nannofossils	D	A


SITE 588 HOLE CORE 20 CORED INTERVAL 178.4–188.0 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. plesiotumida
NN11A
NN10
N. continuosa
NN10
A
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
IW
5G 8/1 ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?) underlain by iron sulfide
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, subtle, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, very subtle, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?) subtle

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9), firm, with abundant blebs of iron sulfide and light greenish gray ash(?) beds.

SMEAR SLIDE SUMMARY

	4, 74
	D
Composition:	
Volcanic glass	R
Foraminifers	C
Calc. nannofossils	A

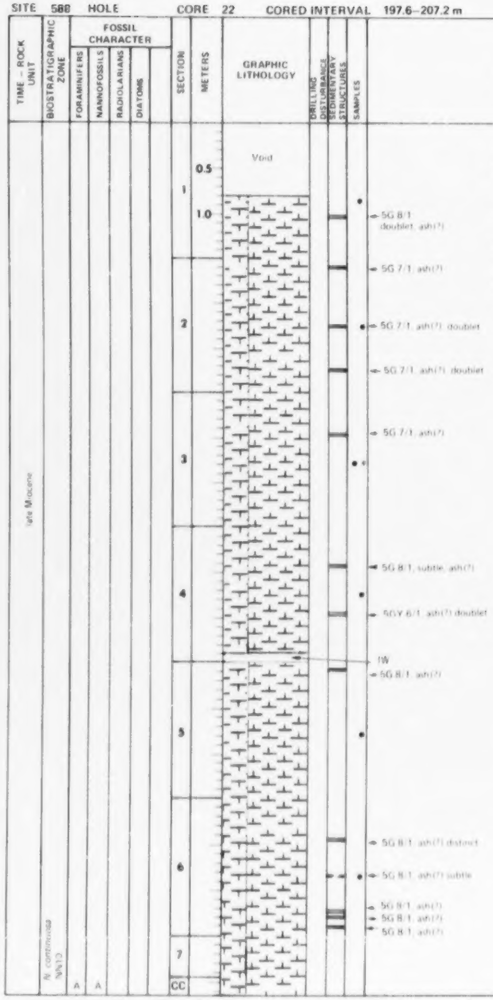

SITE 588 HOLE CORE 21 CORED INTERVAL 188.0–197.6 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N. continuosa
NN10
A
A
Void
0.5
1.0
1
2
3
4
5
6
7
CC
IW
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, triplet
5G 8/1, ash(?)
5G 8/1, ash(?), doublet
5G 7/1, ash(?) abundant glass
5G 8/1, ash(?), subtle
5G 8/1, ash(?), doublet
5G 8/1, ash(?), quartet
5G 8/1, ash(?), triplet
5G 8/1, ash(?), quartet, subtle
5G 8/1, ash(?)
5G 8/1, ash(?) subtle
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?) underlain by FeS
5G 8/1, ash(?)
5G 8/1, ash(?) triplet
5GY 8/1, ash(?) underlain by FeS

FORAMINIFER-BEARING NANNOFOSSIL OOZE, firm, much more frequent ash(?) layers giving the sediment a bluish white (5B 9/1) color, abundant iron sulfide.

SMEAR SLIDE SUMMARY

	1, 73	2, 4
	D	M
Composition:		
Volcanic glass	–	C
Foraminifers	C	R
Calc. nannofossils	D	A

SITE 588 HOLE CORE 22 CORED INTERVAL 197.6–207.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN10
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
IW
5G 8/1 doublet, ash(?)
5G 7/1, ash(?)
5G 7/1, ash(?), doublet
5G 7/1, ash(?), doublet
5G 7/1, ash(?)
5G 8/1, subtle, ash(?)
5GY 6/1, ash(?) doublet
5G 8/1, ash(?)
5G 8/1, ash(?) distinct
5G 8/1, ash(?) subtle
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)

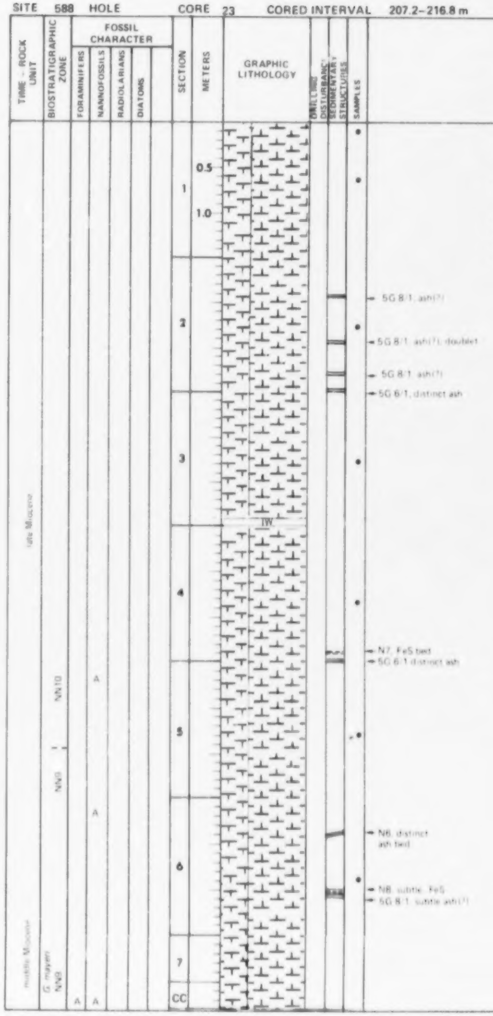
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, firm, very light greenish gray (5GY 8/1) becoming whiter (N9) and having less iron sulfide downcore.

SMEAR SLIDE SUMMARY

Composition:	3, 81 D
Quartz	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	A

SITE 588 HOLE CORE 23 CORED INTERVAL 207.2–216.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
middle Miocene
NN10
NN9
G. mayeri
NN9
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
IW
5G 8/1, ash(?)
5G 8/1, ash(?), doublet
5G 8/1, ash(?)
5G 6/1, distinct ash
N7, FeS bed
5G 6/1 distinct ash
N8, distinct ash bed
N8, subtle, FeS
5G 8/1, subtle ash(?)

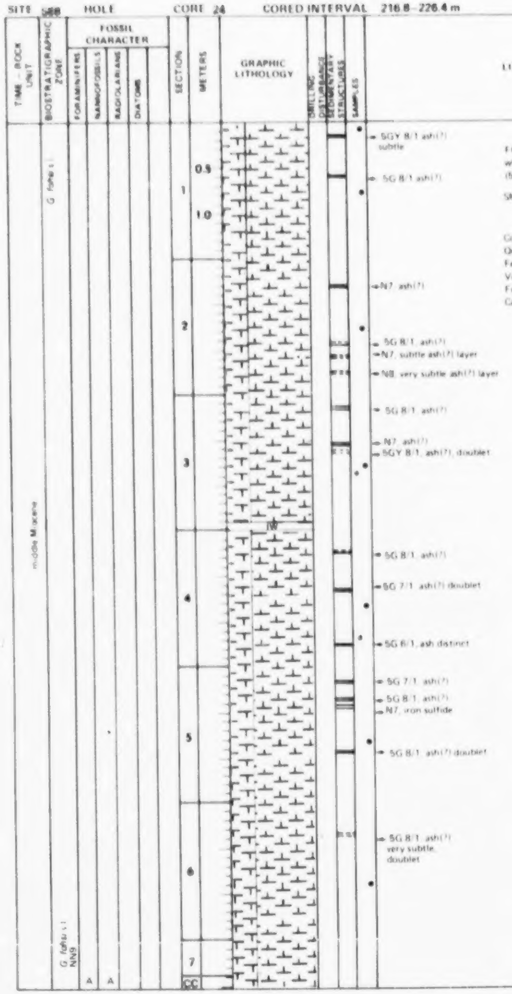
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, wite (N9), little iron sulfide, very homogeneous.

SMEAR SLIDE SUMMARY:

Composition:	5, 77 D
Volcanic glass	R
Foraminifers	C
Calc. nannofossils	A

SITE 588 HOLE CORE 24 CORED INTERVAL 216.8–226.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
G. fohsi s.l.
NN9
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
IW
5GY 8/1 ash(?) subtle
5G 8/1 ash(?)
N7 ash(?)
5G 8/1, ash(?)
N7, subtle ash(?) layer
N8, very subtle ash(?) layer
5G 8/1, ash(?)
N7, ash(?)
5GY 8/1, ash(?), doublet
5G 8/1, ash(?)
5G 7/1, ash(?) doublet
5G 8/1, ash distinct
5G 7/1, ash(?)
5G 8/1, ash(?)
N7, iron sulfide
5G 8/1, ash(?) doublet
5G 8/1, ash(?) very subtle, doublet

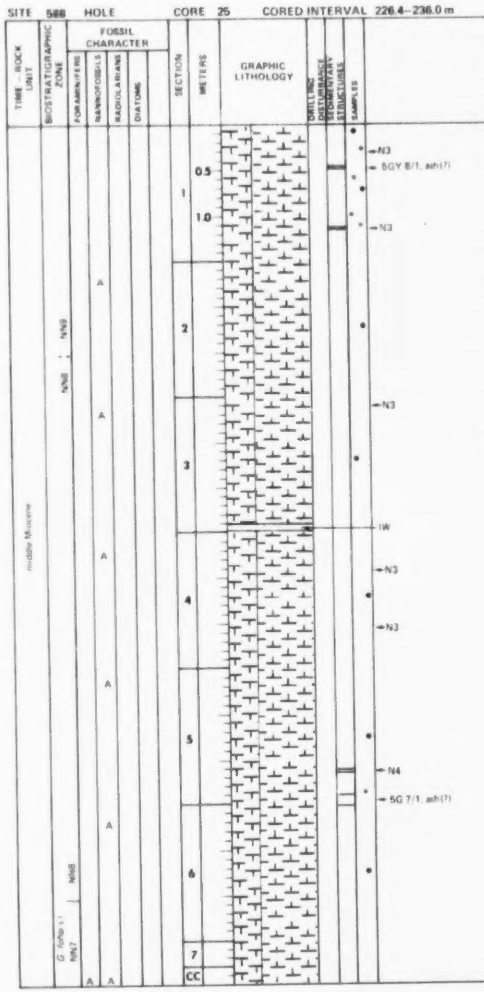
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, somewhat softer than overlying core, very light greenish gray (5GY 9/1).

SMEAR SLIDE SUMMARY

	3, 82	4, 128
	D	M
Composition:		
Quartz	T	T
Feldspar	–	T
Volcanic glass	T	R
Foraminifers	C	C
Calc. nannofossils	A	A

SITE 588 HOLE CORE 25 CORED INTERVAL 226.4–236.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN9
NN8
NN8
G. fohsi s.l.
NN7
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N3
5GY 8/1, ash(?)
N3
N3
IW
N3
N3
N4
5G 7/1, ash(?)

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous. Very light gray to very light greenish gray (N8 to 5GY 8/1).

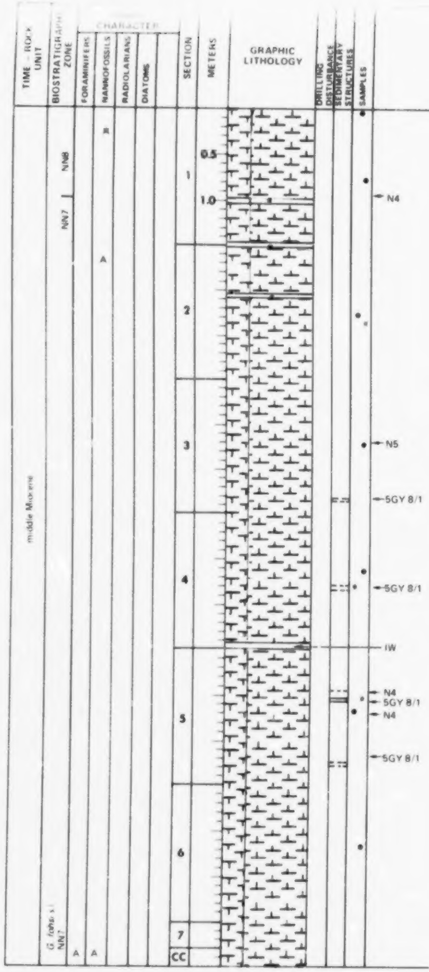
Light greenish gray (5GY 8/1) laminae containing rare or traces volcanic elements.

Dark gray (N3 to N4) laminae and nodules of iron sulfide.

SMEAR SLIDE SUMMARY:

	1, 32	1, 64	1, 107	1, 108	5, 148
	M	D	–	–	–
Texture:					
Sand	–	C	C	R	–
Silt	C	A	A	C	–
Clay	D	D	A	D	–
Composition:					
Heavy minerals	–	–	–	–	T
Volcanic glass	–	–	–	–	T
Pyrite	A	–	T	–	T
Foraminifers	T	C	C	C	C
Calc. nannofossils	A	D	D	D	D

SITE 588


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN8
NN7
G. fohsi s.l.
NN7
R
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N4
N5
5GY 8/1
5GY 8/1
IW
N4
5GY 8/1
N4
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, firm, homogeneous

Very, light gray to light greenish gray (N8 to 5GY 8/1)

Light greenish gray (5GY 8/1) laminae, rare volcanic elements

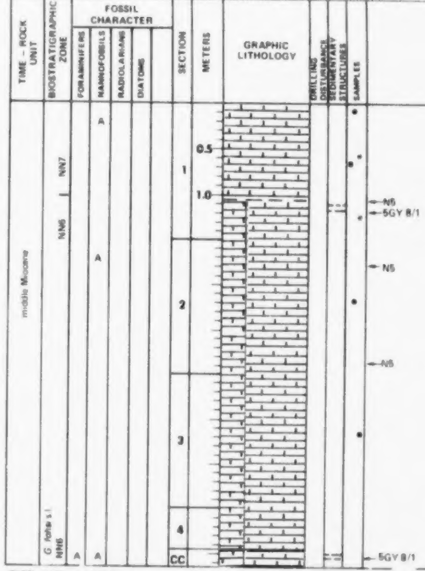
Dark gray (N3 to N4) laminae and nodules of iron sulfide

* Artificial gap compaction

SMEAR SLIDE SUMMARY

	2, 83 D	4, 81 M	5, 48 M
Texture:			
Silt	C	C	C
Clay	D	D	D
Composition:			
Heavy minerals	–	T	R
Pyrite	T	T	–
Foraminifers	C	C	R
Calc. nannofossils	D	D	D
Sponge spicules	T	–	–

SITE 588 HOLE A CORE 2 CORED INTERVAL 245.6–250.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN7
NN6
G. fohsi s.l.
NN6
A
A
A
A
1
2
3
4
CC
0.5
1.0
N5
5GY 8/1
N5
N5
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous

Very light gray (N8) to very light greenish gray (5GY 8/1)

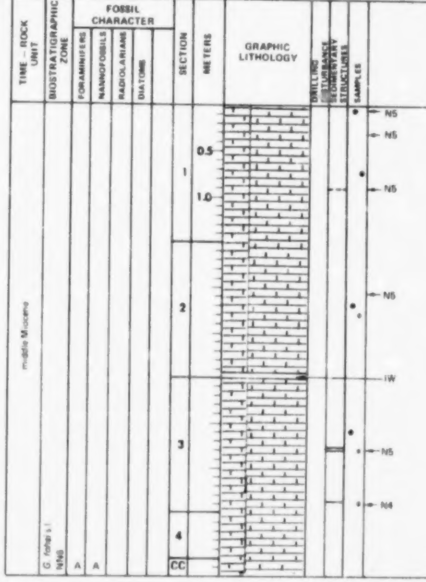
Light greenish gray laminae (5GY 8/1)

Gray laminae and nodules (N5) of iron sulfide

SMEAR SLIDE SUMMARY

	1, 80 D	1, 130 D	3, 80
Texture:			
Silt	–	C	C
Clay	–	D	D
Composition:			
Volcanic glass	–	T	–
Foraminifers	R	C	C
Calc. nannofossils	D	D	D

SITE 588 HOLE A CORE 3 CORED INTERVAL 250.6–255.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
1
2
3
4
CC
0.5
1.0
N5
N5
N5
N5
IW
N5
N4

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous

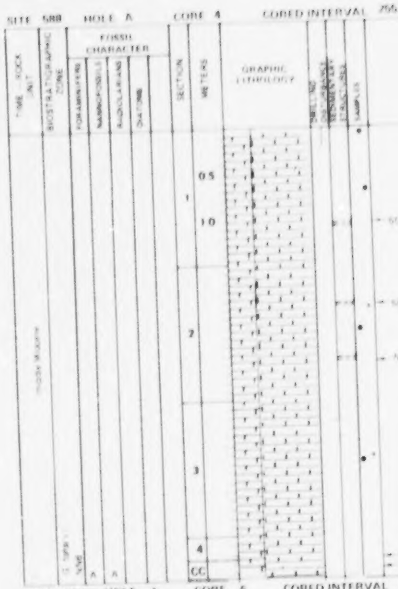
Very light gray (N8) to very light greenish gray (5GY 8/1)

Light gray (N7) to dark gray (N3) laminae and nodules of iron sulfide

SMEAR SLIDE SUMMARY

	2, 77 D	3, 72 M	3, 130 D
Texture:			
Silt	C	C	C
Clay	D	D	D
Composition:			
Quartz	–	–	T
Heavy minerals	–	T	–
Pyrite	–	T	–
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 588 HOLE A CORE 4 CORED INTERVAL 255.6–260.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
A
A
0.5
1.0
1
2
3
4
CC
5GY 8/1
5GY 8/1
N5
N5
N5

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

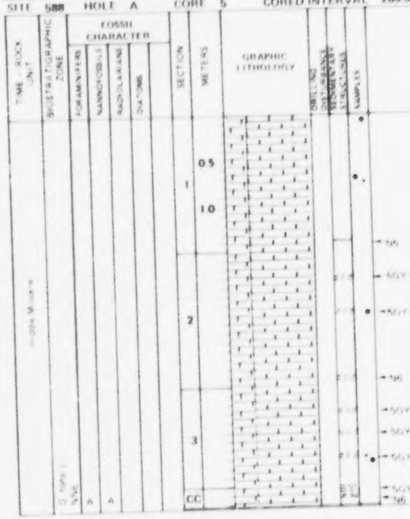
Light greenish gray (5GY 8/1) laminae.

Medium gray (N5) laminae of iron sulfide.

SMEAR SLIDE SUMMARY

	2, 44	1, 70
	M	D
Texture:		
Silt	C	T
Clay	D	D
Composition:		
Heavy minerals	R	
Volcanic glass	T	–
Pyrite	R	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 588 HOLE A CORE 5 CORED INTERVAL 260.6–265.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
A
A
0.5
1.0
1
2
3
CC
N6
5GY 8/1
5GY 8/1
N6
5GY 8/1
5GY 8/1
5GY 8/1
5GY 8/1
N6

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

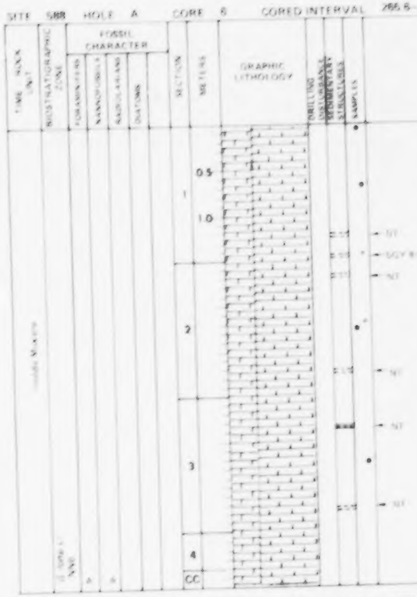
Light greenish gray (5GY 8/1) laminae.

Medium gray (N5, N6) laminae of iron sulfide.

SMEAR SLIDE SUMMARY

	1, 80	3, 76
	D	M
Texture:		
Silt		C
Clay		D
Composition:		
Heavy minerals		R
Volcanic glass	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 588 HOLE A CORE 6 CORED INTERVAL 265.6–270.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
A
A
0.5
1.0
1
2
3
4
CC
N7
5GY 8/1
N7
N7
N7
N7

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

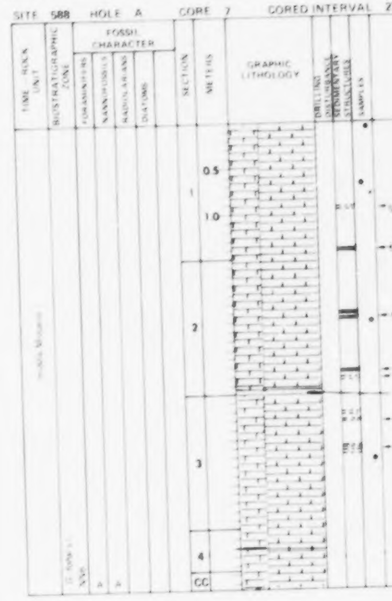
Light greenish gray (5GY 8/1) laminae.

Light gray (N7) laminae of iron sulfide.

SMEAR SLIDE SUMMARY

	1, 148	2, 80
	M	D
Composition:		
Heavy minerals	T	T
Pyrite	T	T
Foraminifers	R	C
Calc. nannofossils	C	D

SITE 588 HOLE A CORE 7 CORED INTERVAL 270.6–275.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
A
A
0.5
1.0
1
2
3
4
CC
5GY 8/1
5GY 8/1
N6–N6
N5
5GY 8/1
IW
5GY 8/1
N5–N6

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

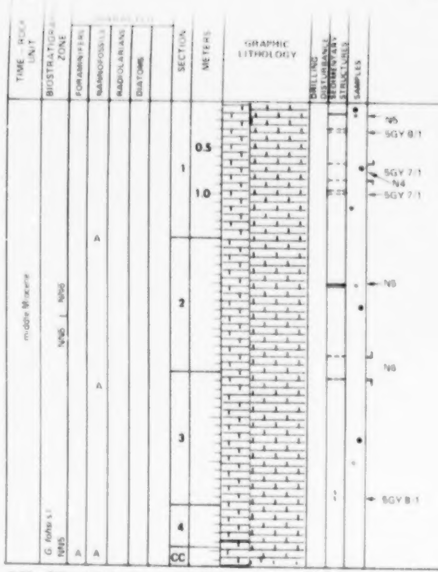
With light greenish gray (5GY 8/1) laminae.

Medium gray (N4–N6) laminae of iron sulfide.

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture:	
Silt	C
Clay	D
Composition:	
Heavy minerals	R
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE [illegible]


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN5 | NN6
G. fohsi s.l.
NN5
A
A
A
A
0.5
1.0
1
2
3
4
CC
N5
5GY 8/1
5GY 7/1
N4
5GY 7/1
N6
N6
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

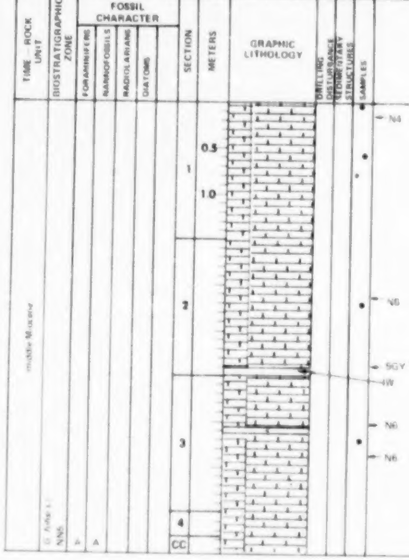
Light greenish gray (5GY 7/1) laminae.

Medium gray (N4–N6) laminae and nodules of iron sulfide.

SMEAR SLIDE SUMMARY

	1, 17	2, 95	3, 98
	D	D	D
Texture			
Silt	C	C	C
Clay	D	D	D
Composition			
Quartz	–	T	T
Heavy minerals	–	T	T
Foraminifers	C	C	R
Calc. nannofossils	D	D	D

SITE 588 HOLE A CORE 9 CORED INTERVAL 280.6–285.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN5
A
A
0.5
1.0
1
2
3
4
CC
N4
N6
5GY 7/1
W
N6
N6

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

Light greenish gray (5GY 7/1) burrows.

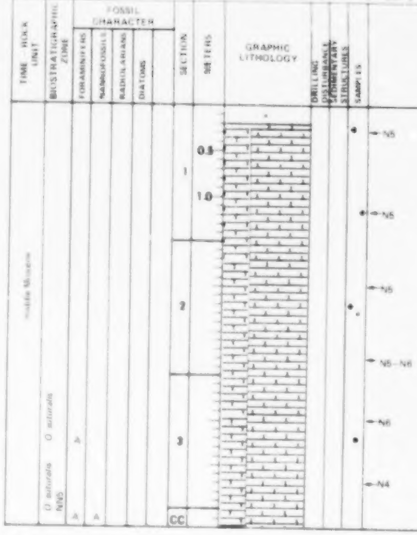
Medium gray (N4 to N6) laminae and nodules of iron sulfide.

* Artificial gap due to drilling.

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture	
Sand	R
Silt	C
Clay	D
Composition	
Quartz	T
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE [illegible] CORED INTERVAL [illegible]


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
O. suturalis
O. suturalis
NN5
A
A
A
0.5
1.0
1
2
3
CC
N5
N5
N5
N5–N6
N6
N4

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous.

Very light gray (N8) to very light greenish gray (5GY 8/1).

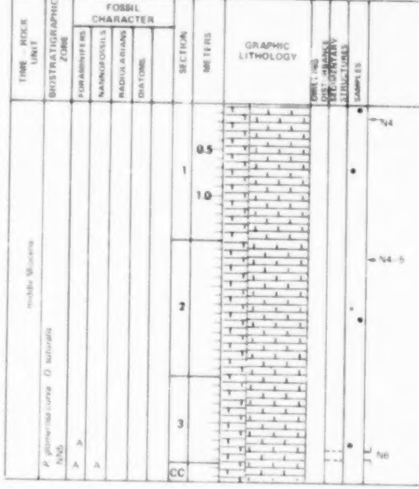
Medium gray (N4 to N6) laminae of iron sulfide.

*Artificial gap due to drilling.

SMEAR SLIDE SUMMARY

	2, 80
	D
Texture	
Silt	C
Clay	D
Composition	
Quartz	T
Heavy minerals	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE 11 CORED INTERVAL 290.6–295.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva O. suturalis
NN5
A
A
A
0.5
1.0
1
2
3
CC
N4
N4–5
N6

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous.

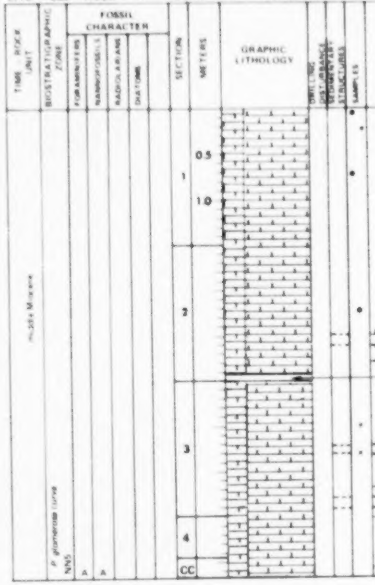
Very light gray (N8) to very light greenish gray (5GY 8/1).

Medium gray (N4 to N6) laminae and nodules of iron sulfide.

SMEAR SLIDE SUMMARY

	2, 63
	D
Texture	
Silt	C
Clay	D
Composition	
Quartz	T
Heavy minerals	R
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE 12 CORED INTERVAL 295.6–300.6 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva
NN5
A
A
1
2
3
4
CC
0.5
1.0
5GY 8/1
5G 8/1
5GY 7/1
IW
N8–5GY 8/1
N8
N8
5GY 8/1
N8
N8

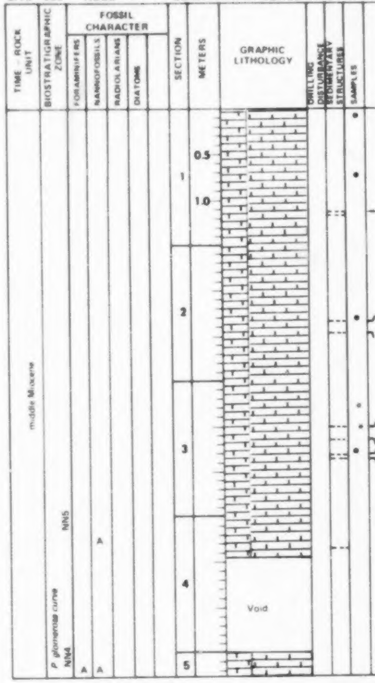
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, homogeneous. Very light gray (N8) to very light greenish gray (5GY 8/1), with light greenish gray (5GY 7/1) mottles and very light gray (N8) mottles.

SMEAR SLIDE SUMMARY

	1, 31 D	3, 52 M	3, 84 D
Texture:			
Silt	C	–	–
Clay	D	–	–
Composition:			
Quartz	–	T	T
Heavy minerals	T	T	–
Pyrite	–	T	–
Foraminifers	C	R	C
Calc. nannofossils	D	D	D

SITE 588 HOLE A CORE 13 CORED INTERVAL 300.6–305.6 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN5
P. glomerosa curva
NN4
A
A
A
1
2
3
4
5
0.5
1.0
Void
N7½
N7
N7
N7

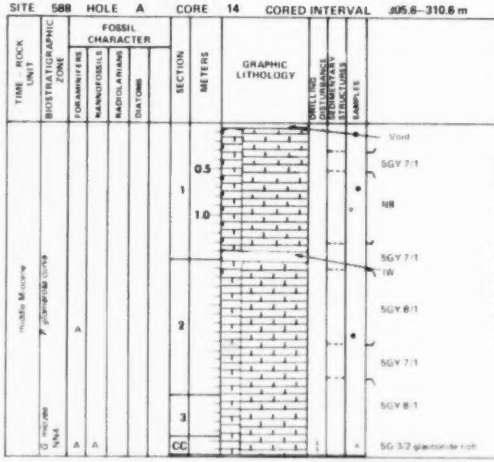
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) with a few, very subtle, darker bands; burrowing is moderate; overall very homogeneous.

SMEAR SLIDE SUMMARY

	3, 56 M	3, 41 D
Composition:		
Quartz	T	T
Heavy minerals	T	–
Volcanic glass	T	–
Foraminifers	C	R
Calc. nannofossils	A	D

SITE 588 HOLE A CORE 14 CORED INTERVAL 305.6–310.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva
G. miozea
NN4
A
A
A
1
2
3
CC
0.5
1.0
Void
5GY 7/1
N8
5GY 7/1
IW
5GY 8/1
5GY 7/1
5GY 8/1
5G 3/2 glauconite rich

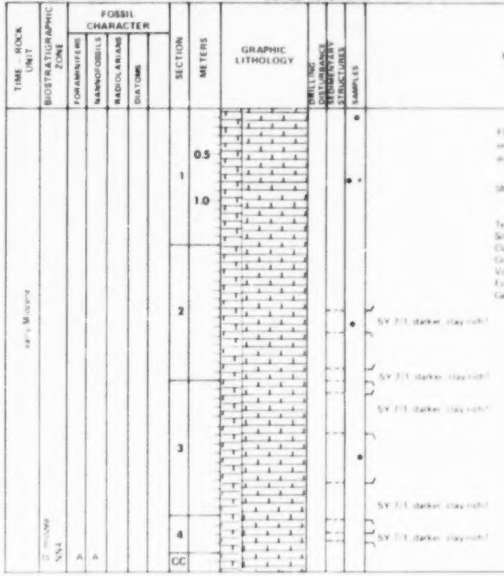
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), abundant burrows and iron sulfide, core becomes greener with increasing depth.

SMEAR SLIDE SUMMARY

	1, 98 D	CC M
Composition		
Quartz	T	T
Feldspar	–	T
Heavy minerals	T	–
Volcanic glass	–	T
Glauconite	–	A
Pyrite	T	–
Foraminifers	C	R
Calc. nannofossils	A	C

SITE 588 HOLE A CORE 15 CORED INTERVAL 310.6–315.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN4
A
A
1
2
3
4
CC
0.5
1.0
5Y 7/1 darker (clay rich)
5Y 7/1 darker (clay rich)
5Y 7/1 darker (clay rich)
5Y 7/1 darker (clay rich)
5Y 7/1 darker (clay rich)

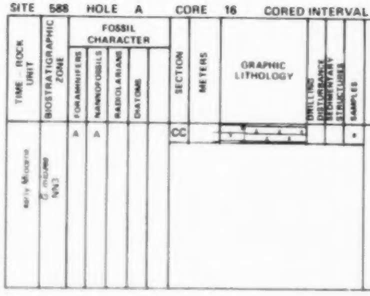
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, very light greenish gray (5GY 7/1), abundant burrowing activity, otherwise almost homogeneous.

SMEAR SLIDE SUMMARY

	1, 74 D
Texture:	
Silt	C
Clay	D
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE 16 CORED INTERVAL 315.6–325.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN3
A
A
CC

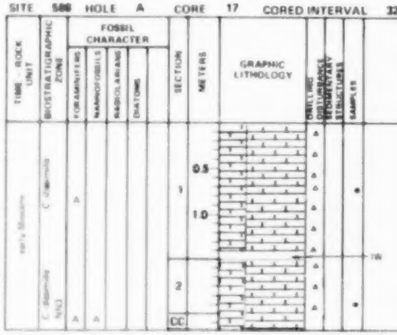
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, very firm, greenish gray (5GY 6/1), homogeneous.

SMEAR SLIDE SUMMARY

	CC, 8 D
Composition	
Quartz	T
Feldspar	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE 17 CORED INTERVAL 325.2–334.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
C. dissimilis
C. dissimilis
NN3
A
A
A
1
2
CC
0.5
1.0
IW

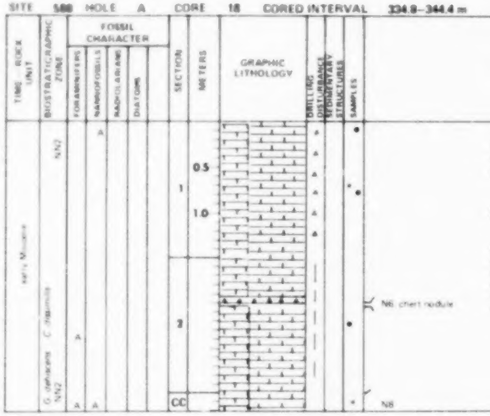
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, very firm, greenish gray (5GY 6/1), homogeneous; drilling disturbance has reduced interval to rubble.

SMEAR SLIDE SUMMARY

	2, 45 D
Composition	
Heavy minerals	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE A CORE 18 CORED INTERVAL 334.8–344.4 m

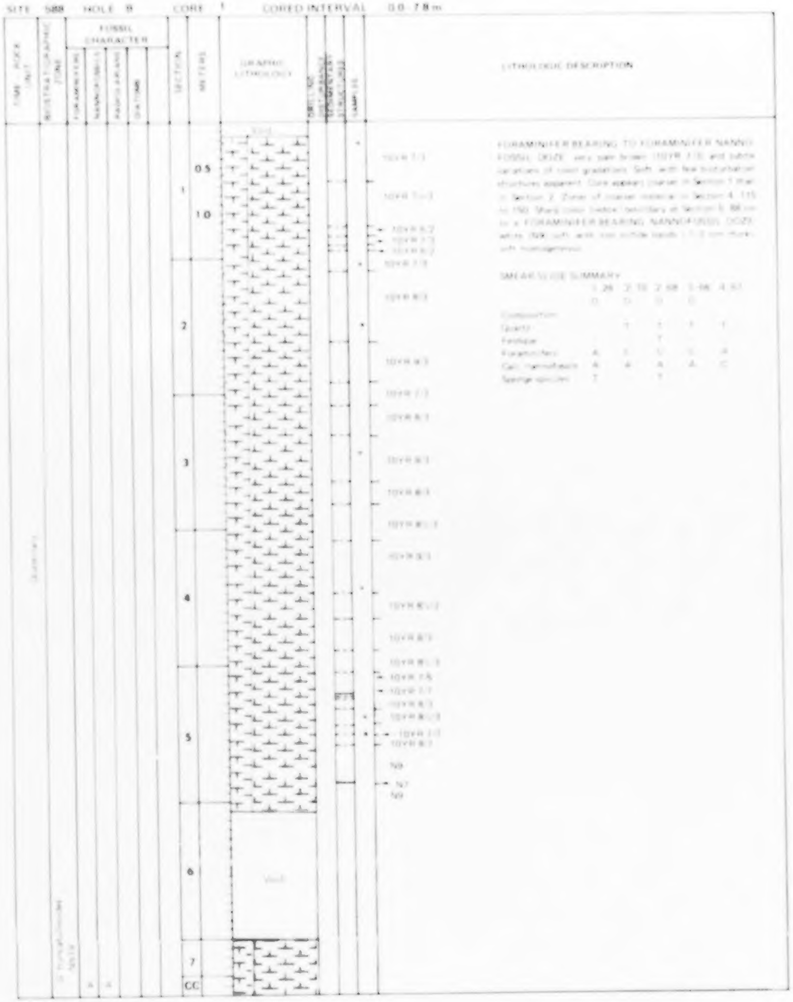

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN2
G. dehiscens
C. dissimilis
NN2
A
A
A
A
1
2
CC
0.5
1.0
N6 chert nodule
N8

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, very firm, light greenish gray (5GY 7/1) to greenish gray (5GY 6/1), homogeneous throughout, moderately deformed.

SMEAR SLIDE SUMMARY

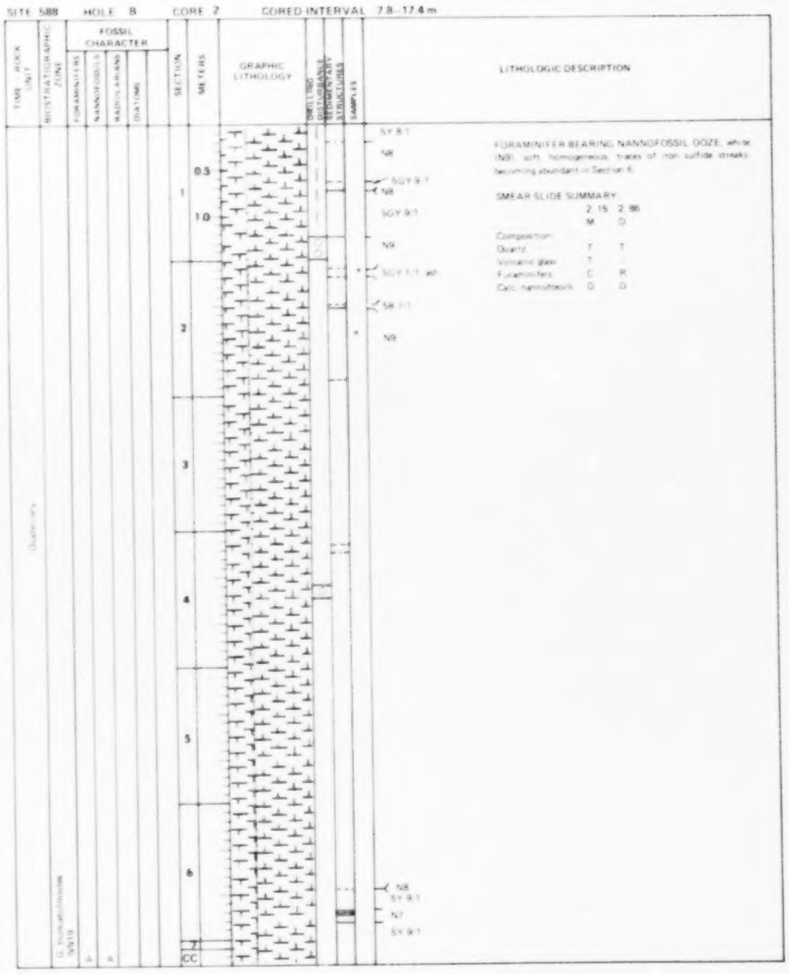
	1, 70 D	CC D
Composition		
Quartz	T	–
Heavy minerals	T	–
Glauconite	T	–
Foraminifers	C	C
Calc. nannofossils	A	D


SITE 588 HOLE B CORE 1 CORED INTERVAL 0.0–7.8 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
G. truncatulinoides
NN19
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
Void
10YR 7/3
10YR 7/-3
10YR 6/2
10YR 7/3
10YR 6/2
10YR 7/3
10YR 8/3
10YR 8/3
10YR 7/3
10YR 8/3
10YR 8/3
10YR 8/3
10YR 8/1-3
10YR 8/3
10YR 8/1-2
10YR 8/3
10YR 8/1-3
10YR 7/6
10YR 7/7
10YR 8/3
10YR 8/1-3
10YR 7/3
10YR 8/2
N9
N7
N9

FORAMINIFER BEARING TO FORAMINIFER NANNOFOSSIL OOZE, very pale brown (10YR 7/3) and subtle variations of color gradations. Soft, with few bioturbation structures apparent. Core appears coarser in Section 1 than in Section 2. Zones of coarser material in Section 4, 115 to 150. Sharp color (redox) boundary at Section 5, 88 cm to a FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9), soft, with iron sulfide bands (1-3 cm thick), soft, homogeneous.

SMEAR SLIDE SUMMARY

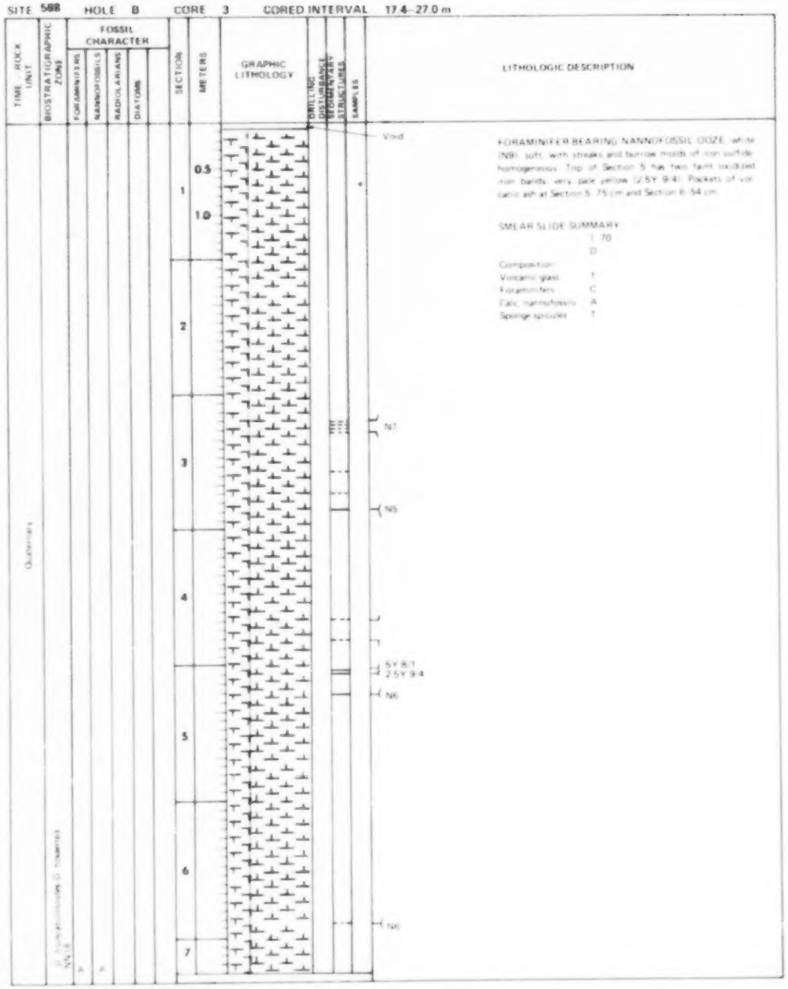
	1, 26	2, 10	2, 68	3, 86	4, 93
	D	D	D	D	
Composition:					
Quartz	—	T	T	T	T
Feldspar	—	—	T	—	—
Foraminifers	A	C	C	C	A
Calc. nannofossils	A	A	A	A	C
Sponge spicules	T	—	T	—	—


SITE 588 HOLE B CORE 2 CORED INTERVAL 7.8–17.4 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
G. truncatulinoides
NN19
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
N8
5GY 9/1
N8
5GY 9/1
N9
5GY 7/1, wf
5B 7/1
N9
N8
5Y 8/1
N7
5Y 8/1

FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9), soft, homogeneous, traces of iron sulfide streaks becoming abundant in Section 6.

SMEAR SLIDE SUMMARY

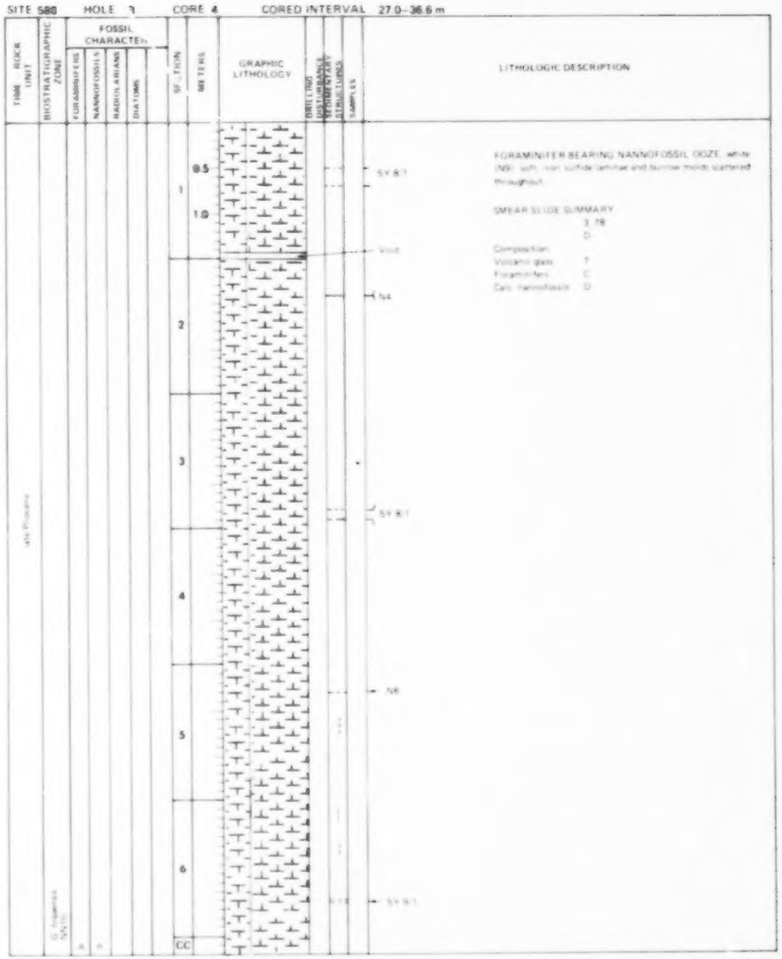
	2, 15	2, 86
	M	D
Composition:		
Quartz	T	T
Volcanic glass	T	—
Foraminifers	C	R
Calc. nannofossils	D	D


SITE 588 HOLE B CORE 3 CORED INTERVAL 17.4–27.0 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19
A
A
1
2
3
4
5
6
7
0.5
1.0
Void
N7
N5
5Y 8/1
2.5Y 9/4
N6
N6

FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9), soft, with streaks and burrow molds of iron sulfide, homogeneous. Top of Section 5 has two faint oxidized iron bands, very pale yellow (2.5Y 9/4). Pockets of volcanic ash at Section 5, 75 cm and Section 6, 54 cm.

SMEAR SLIDE SUMMARY

	1, 70
	D
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	A
Sponge spicules	T

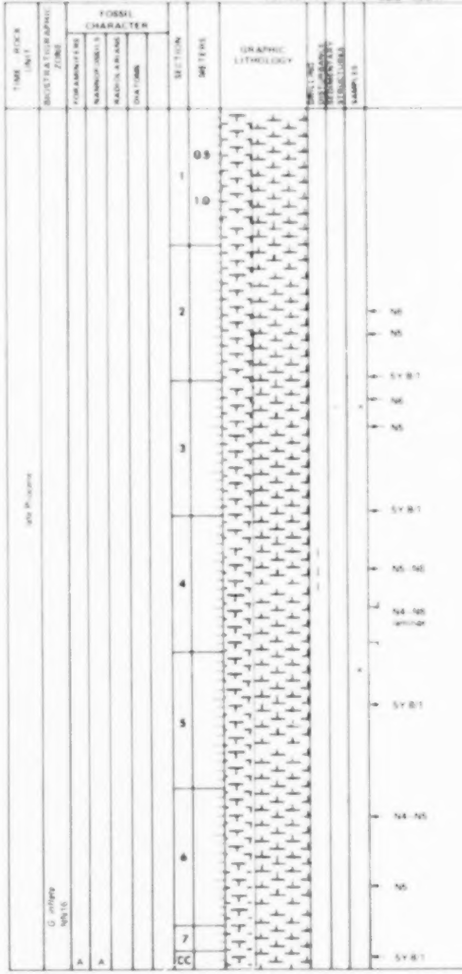

SITE 588 HOLE B CORE 4 CORED INTERVAL 27.0–36.6 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
G. tosaensis
A
A
1
2
3
4
5
6
CC
0.5
1.0
5Y 8/1
Void
N4
5Y 8/1
N8
5Y 8/1

FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9), soft, iron sulfide laminae and burrow molds scattered throughout.

SMEAR SLIDE SUMMARY

	3, 78
	D
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 5 CORED INTERVAL 38.6–46.2 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN16
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N6
N5
5Y 8/1
N6
N5
5Y 8/1
N5–N6
N4–N6 laminae
5Y 8/1
N4–N5
N5
5Y 8/1

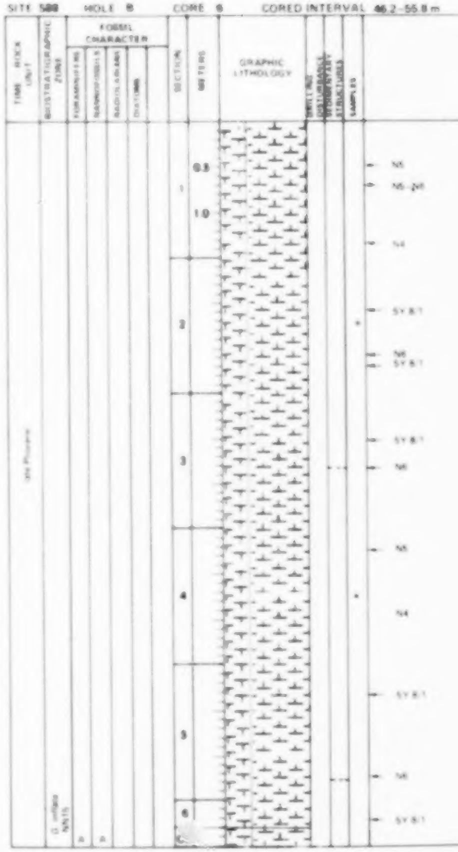
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY

	1, 20	5, 20
	D	D
Texture:		
Silt	C	
Clay	D	
Composition:		
Heavy minerals		T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 588 HOLE B CORE 6 CORED INTERVAL 46.2–55.8 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN15
A
A
1
2
3
4
5
6
CC
0.5
1.0
N5
N5–2/4
N4
5Y 8/1
N6
5Y 8/1
5Y 8/1
N6
N5
N4
5Y 8/1
N6
5Y 8/1

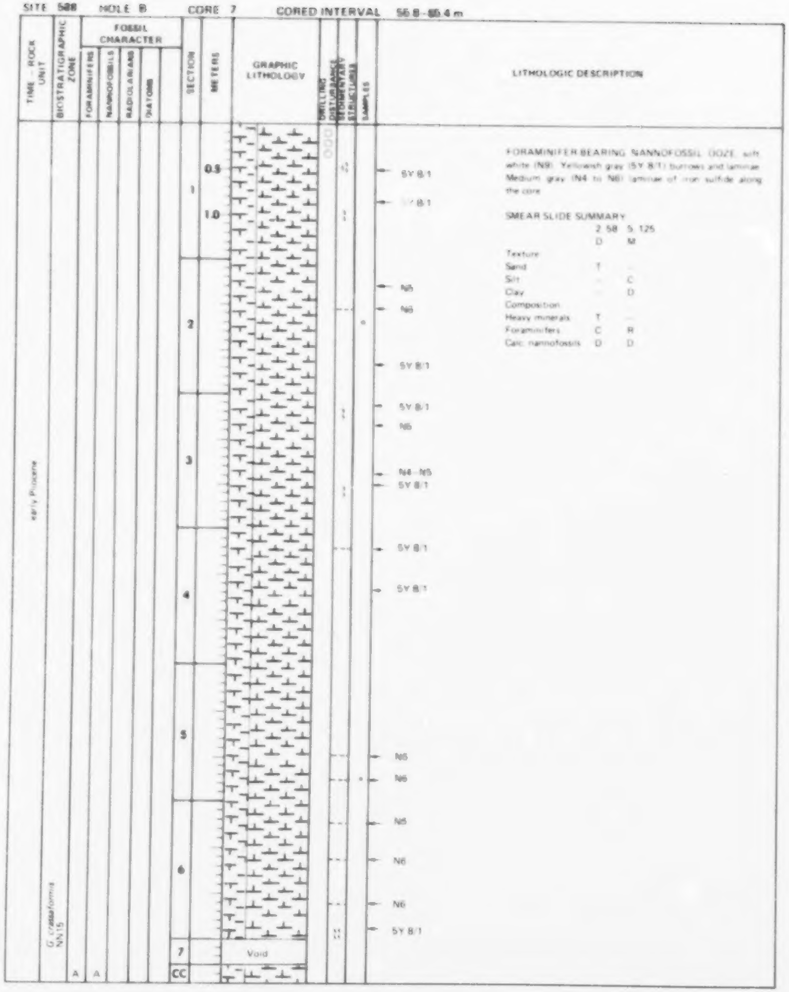
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY

	2, 63	4, 70
	D	D
Texture:		
Silt	C	C
Clay	D	–
Composition:		
Heavy minerals	T	–
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	–	T

SITE 588 HOLE B CORE 7 CORED INTERVAL 56.8–65.4 m

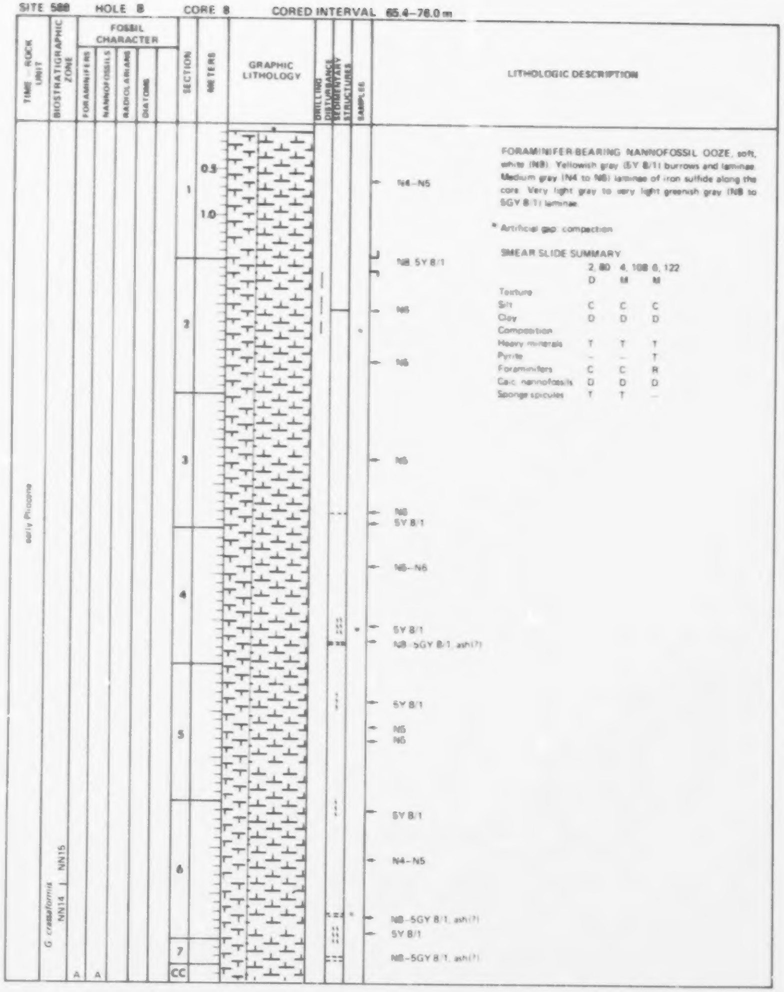

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. crassaformis
NN15
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5Y 8/1
5Y 8/1
N5
N6
5Y 8/1
5Y 8/1
N6
N4–N5
5Y 8/1
5Y 8/1
5Y 8/1
N5
N6
N5
N6
N6
5Y 8/1

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core.

SMEAR SLIDE SUMMARY

	2, 58	5, 125
	D	M
Texture		
Sand	T	—
Silt	—	C
Clay	—	D
Composition		
Heavy minerals	T	—
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 588 HOLE B CORE 8 CORED INTERVAL 65.4–76.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. crassaformis
NN14 | NN15
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N4–N5
N8, 5Y 8/1
N5
N6
N5
N8
5Y 8/1
N8–N6
5Y 8/1
N8–5GY 8/1, ash(?)
5Y 8/1
N5
N5
5Y 8/1
N4–N5
N8–5GY 8/1, ash(?)
5Y 8/1
N8–5GY 8/1, ash(?)

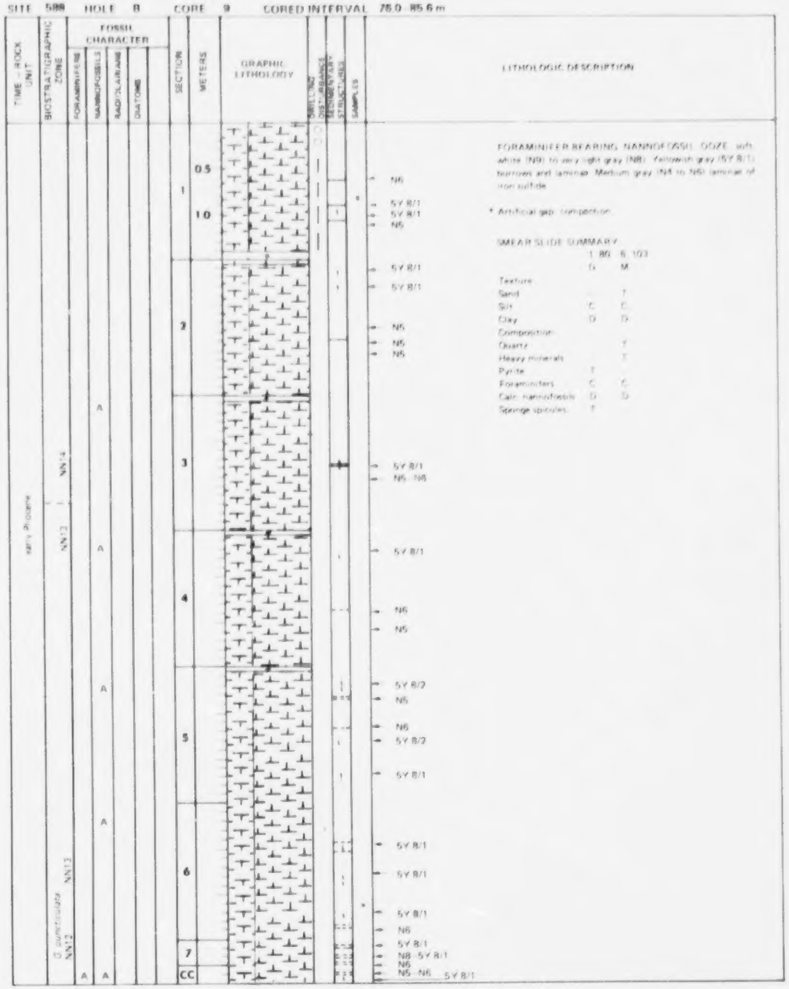
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Very light gray to very light greenish gray (N8 to 5GY 8/1) laminae.

* Artificial gap: compaction

SMEAR SLIDE SUMMARY

	2, 80	4, 108	6, 122
	D	M	M
Texture			
Silt	C	C	C
Clay	D	D	D
Composition			
Heavy minerals	T	T	T
Pyrite	—	—	T
Foraminifers	C	C	R
Calc. nannofossils	D	D	D
Sponge spicules	T	T	—

SITE 588 HOLE B CORE 9 CORED INTERVAL 78.0–85.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN14
NN13
NN13
G. puncticulata
NN12
A
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N6
5Y 8/1
5Y 8/1
N6
5Y 8/1
5Y 8/1
N5
N5
N5
5Y 8/1
N5–N6
5Y 8/1
N6
N5
5Y 8/2
N5
N6
5Y 8/2
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
N6
5Y 8/1
N8–5Y 8/1
N6
N5–N6
5Y 8/1

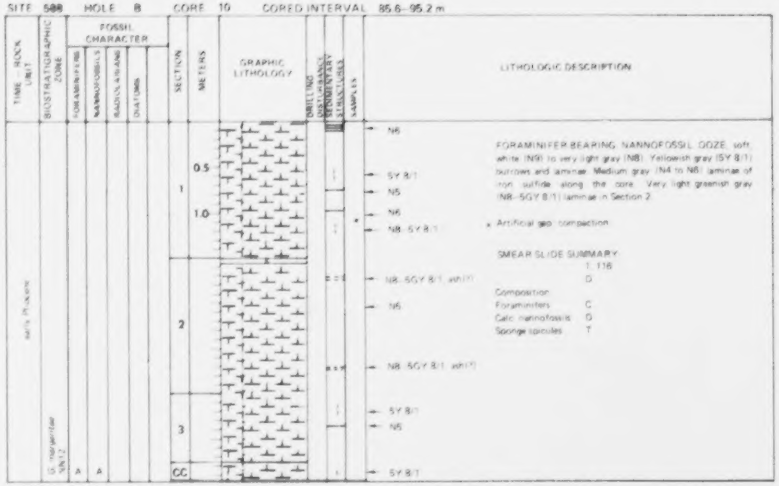
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide.

* Artificial gap: compaction.

SMEAR SLIDE SUMMARY

	1, 86	6, 103
	D	M
Texture:		
Sand	–	T
Silt	C	C
Clay	D	D
Composition:		
Quartz	–	T
Heavy minerals	–	T
Pyrite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	T	

SITE 588 HOLE B CORE 10 CORED INTERVAL 85.6–95.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. margaritae
NN12
A
A
0.5
1.0
1
2
3
CC
N6
5Y 8/1
N5
N6
N8–5Y 8/1
N8–5GY 8/1, ash(?)
N5
N8–5GY 8/1, ash(?)
5Y 8/1
N5
5Y 8/1

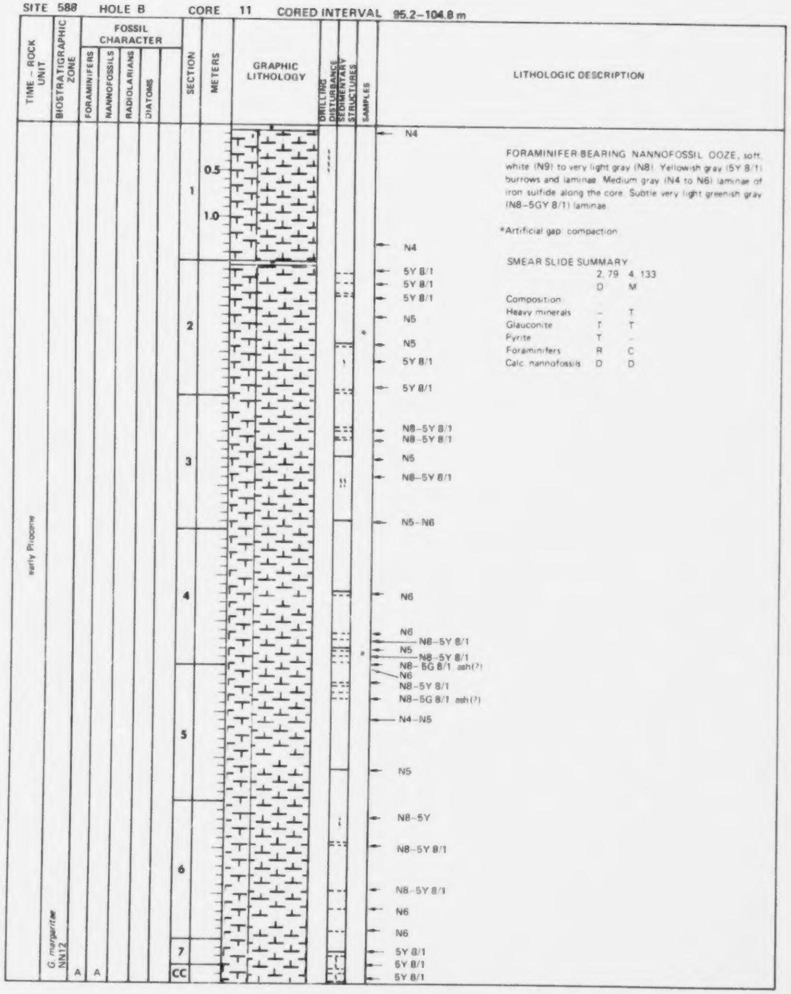
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Very light greenish gray (N8–5GY 8/1) laminae in Section 2.

* Artificial gap: compaction.

SMEAR SLIDE SUMMARY

	1, 116
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 588 HOLE B CORE 11 CORED INTERVAL 95.2–104.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. margaritae
NN12
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N4
N4
5Y 8/1
5Y 8/1
5Y 8/1
N5
N5
5Y 8/1
5Y 8/1
N8–5Y 8/1
N8–5Y 8/1
N5
N8–5Y 8/1
N5–N6
N6
N6
N8–5Y 8/1
N5
N8–5Y 8/1
N8–5G 8/1, ash(?)
N6
N8–5Y 8/1
N8–5G 8/1, ash(?)
N4–N5
N5
N8–5Y
N8–5Y 8/1
N8–5Y 8/1
N6
N6
5Y 8/1
5Y 8/1
5Y 8/1
*

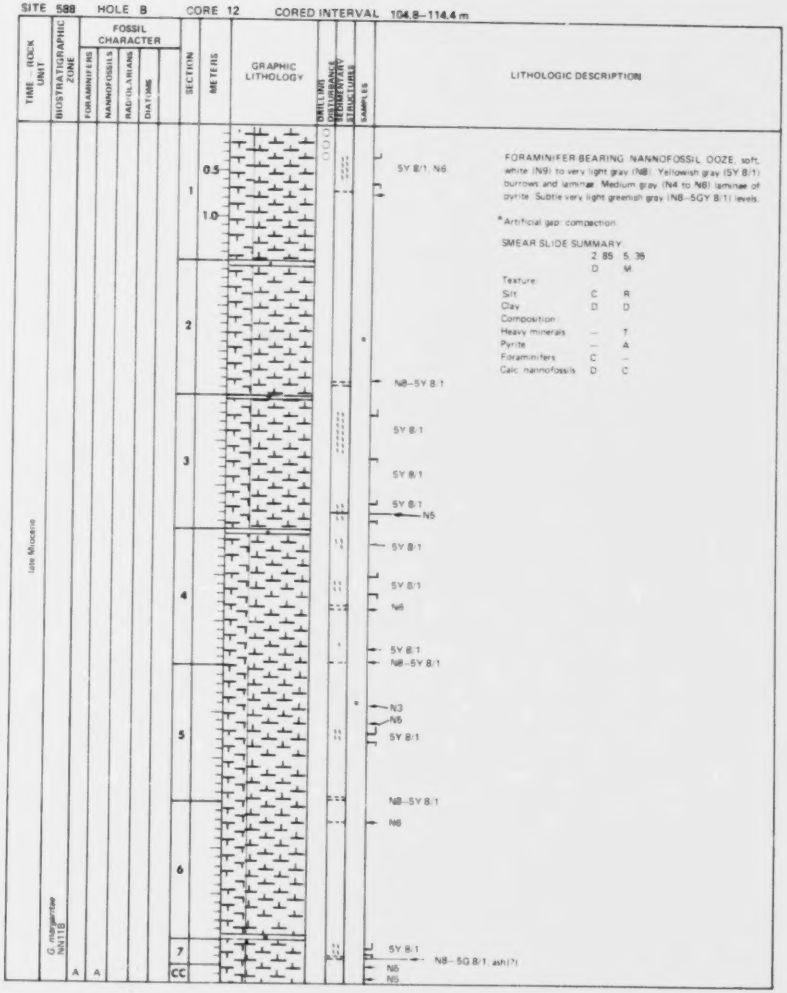
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Subtle very light greenish gray (N8–5GY 8/1) laminae.

*Artificial gap: compaction

SMEAR SLIDE SUMMARY

	2, 79	4, 133
	D	M
Composition:		
Heavy minerals	–	T
Glauconite	T	T
Pyrite	T	–
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 588 HOLE B CORE 12 CORED INTERVAL 104.8–114.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. margaritae
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1, N6
N8–5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
N5
5Y 8/1
5Y 8/1
N6
5Y 8/1
N8–5Y 8/1
N3
N5
5Y 8/1
N8–5Y 8/1
N6
5Y 8/1
N8–5G 8/1, ash(?)
N6
N5
*

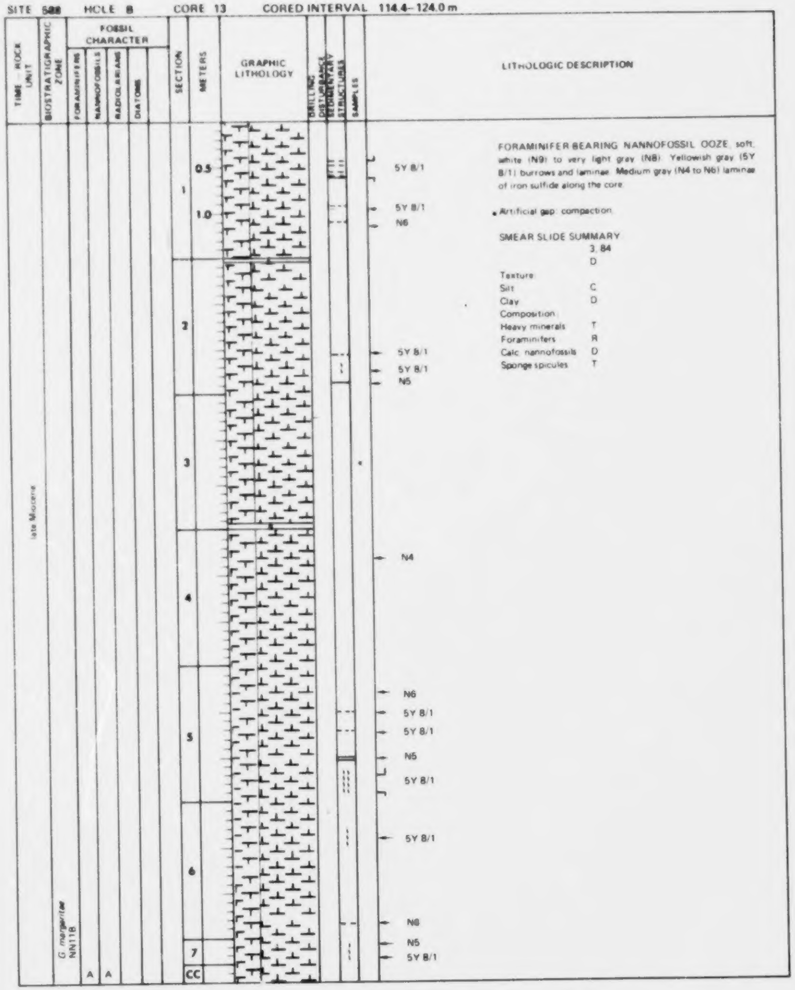
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of pyrite. Subtle very light greenish gray (N8–5GY 8/1) levels.

*Artificial gap: compaction

SMEAR SLIDE SUMMARY

	2, 85	5, 36
	D	M
Texture:		
Silt	C	R
Clay	D	D
Composition:		
Heavy minerals	–	T
Pyrite	–	A
Foraminifers	C	–
Calc. nannofossils	D	C

SITE 588 HOLE B CORE 13 CORED INTERVAL 114.4–124.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. margaritae
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
5Y 8/1
N6
5Y 8/1
5Y 8/1
N5
N4
N6
5Y 8/1
5Y 8/1
N5
5Y 8/1
5Y 8/1
N8
N5
5Y 8/1

LITHOLOGIC DESCRIPTION

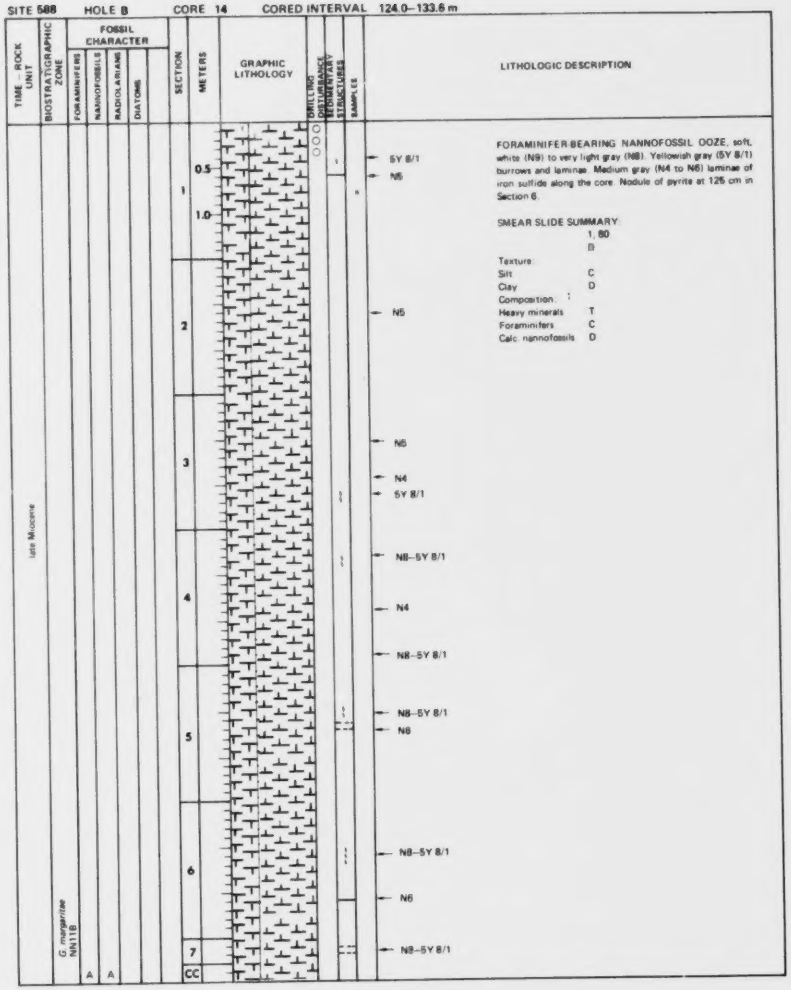
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core.

• Artificial gap: compaction.

SMEAR SLIDE SUMMARY

	3, 84
	D
Texture:	
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

SITE 588 HOLE B CORE 14 CORED INTERVAL 124.0–133.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. margaritae
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
N6
N5
N6
N4
5Y 8/1
N8–5Y 8/1
N4
N8–5Y 8/1
N8–5Y 8/1
N8
N8–5Y 8/1
N6
N8–5Y 8/1

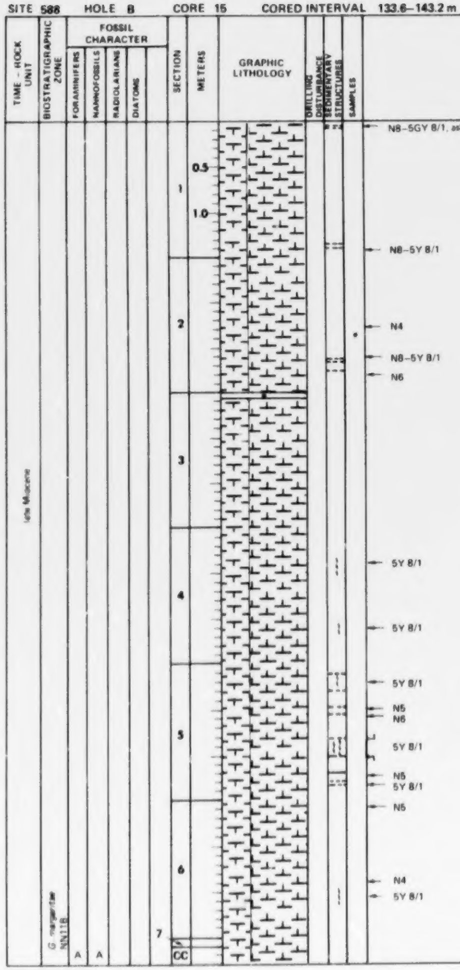
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Nodule of pyrite at 125 cm in Section 6.

SMEAR SLIDE SUMMARY

	1, 80
	B
Texture:	
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 15 CORED INTERVAL 133.6–143.2 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. margaritae
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8–5GY 8/1, ash(?)
N8–5Y 8/1
N4
N8–5Y 8/1
N6
5Y 8/1
5Y 8/1
5Y 8/1
N5
N6
5Y 8/1
N5
5Y 8/1
N5
N4
5Y 8/1

LITHOLOGIC DESCRIPTION

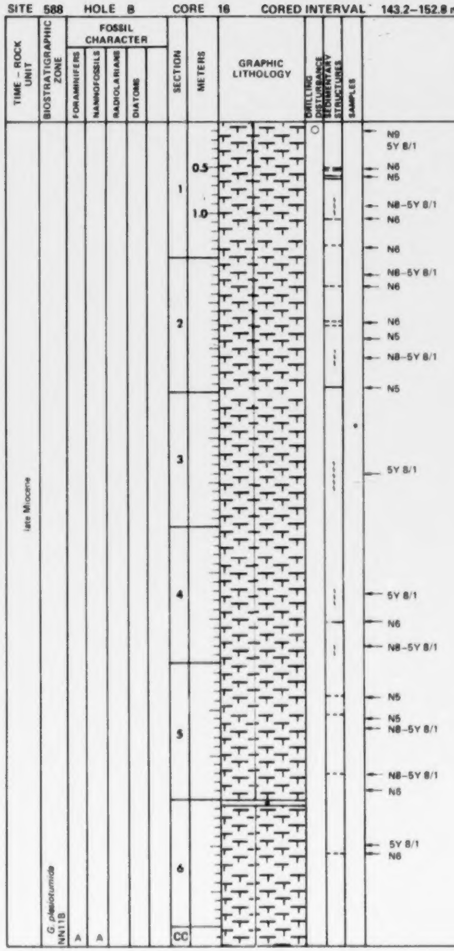
FORAMINIFER BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray burrows and laminae (5Y 8/1). Medium gray (N4 to N6) laminae of iron sulfide along the core.

* Artificial gap: compaction.

SMEAR SLIDE SUMMARY:

	2, 90
Texture:	
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 588 HOLE B CORE 16 CORED INTERVAL 143.2–152.8 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. plesiotumida
NN11B
A
A
1
2
3
4
5
6
CC
0.5
1.0
N9
5Y 8/1
N6
N5
N8–5Y 8/1
N6
N6
N8–5Y 8/1
N6
N6
N5
N8–5Y 8/1
N5
5Y 8/1
5Y 8/1
N6
N8–5Y 8/1
N5
N5
N8–5Y 8/1
N8–5Y 8/1
N6
5Y 8/1
N6

LITHOLOGIC DESCRIPTION

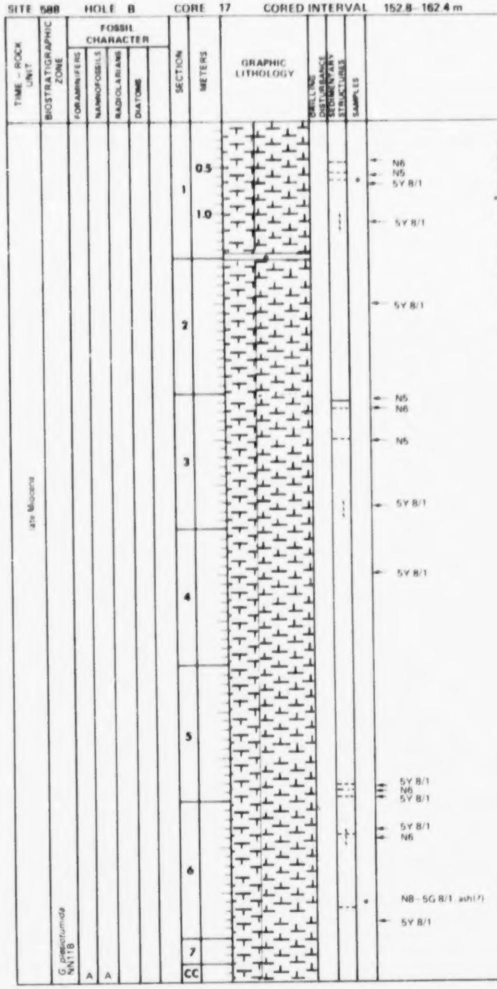
FORAMINIFER BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), with yellowish gray burrows and laminae (5Y 8/1). Medium gray (N4 to N6) laminae of iron sulfide along the core. Ring burrow at 130 cm in Section 5.

* Artificial gap: compaction.

SMEAR SLIDE SUMMARY:

	3, 40 D
Texture:	
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 588 HOLE B CORE 17 CORED INTERVAL 152.8–162.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. plesiotumida
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N6
N5
5Y 8/1
5Y 8/1
5Y 8/1
N5
N6
N5
5Y 8/1
5Y 8/1
5Y 8/1
N6
5Y 8/1
5Y 8/1
N6
N8–5G 8/1 ash(?)
5Y 8/1

LITHOLOGIC DESCRIPTION

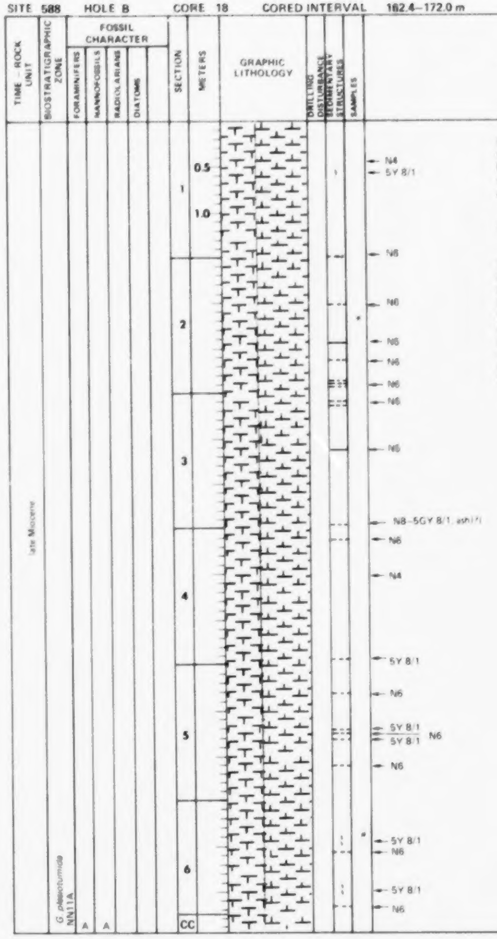
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core.

* Artifical gap: compaction.

SMEAR SLIDE SUMMARY

	1, 70	6, 118
	D	
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Heavy minerals	T	T
Volcanic glass	–	T
Pyrite	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 588 HOLE B CORE 18 CORED INTERVAL 162.4–172.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. plesiotumida
NN11A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N4
5Y 8/1
N6
N6
N6
N6
N6
N6
N6
N8–5GY 8/1, ash(?)
N6
N4
5Y 8/1
N6
5Y 8/1
5Y 8/1
N6
N6
5Y 8/1
N6
5Y 8/1
N6

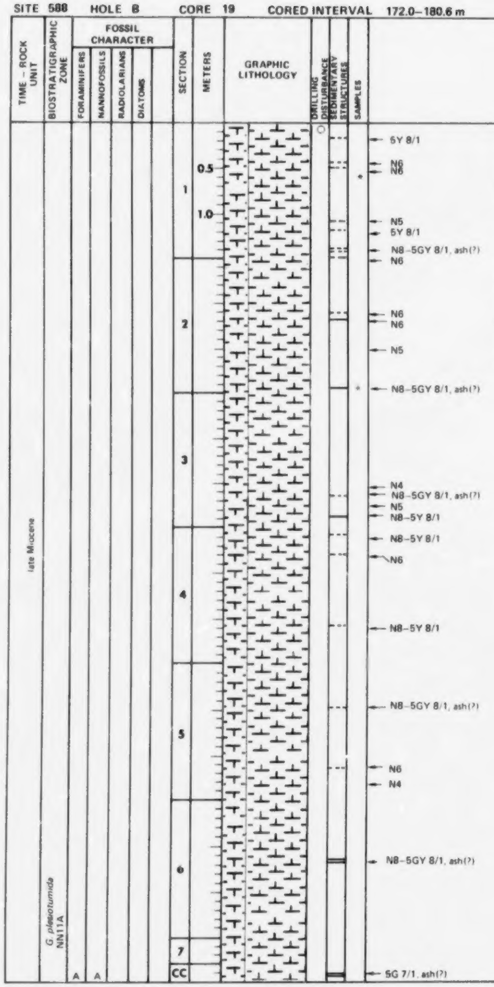
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Yellowish gray (5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Pyrite nodule at 55 cm in Section 4.

SMEAR SLIDE SUMMARY

	2, 58	6, 90
	D	M
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Heavy minerals	–	T
Volcanic glass	T	–
Pyrite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	–	T

SITE 588 HOLE B CORE 19 CORED INTERVAL 172.0–180.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. plesiotumida
NN11A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/1
N6
N6
N5
5Y 8/1
N8–5GY 8/1, ash(?)
N6
N6
N6
N5
N8–5GY 8/1, ash(?)
N4
N8–5GY 8/1, ash(?)
N5
N8–5Y 8/1
N8–5Y 8/1
N6
N8–5Y 8/1
N8–5GY 8/1, ash(?)
N6
N4
N8–5GY 8/1, ash(?)
5G 7/1, ash(?)

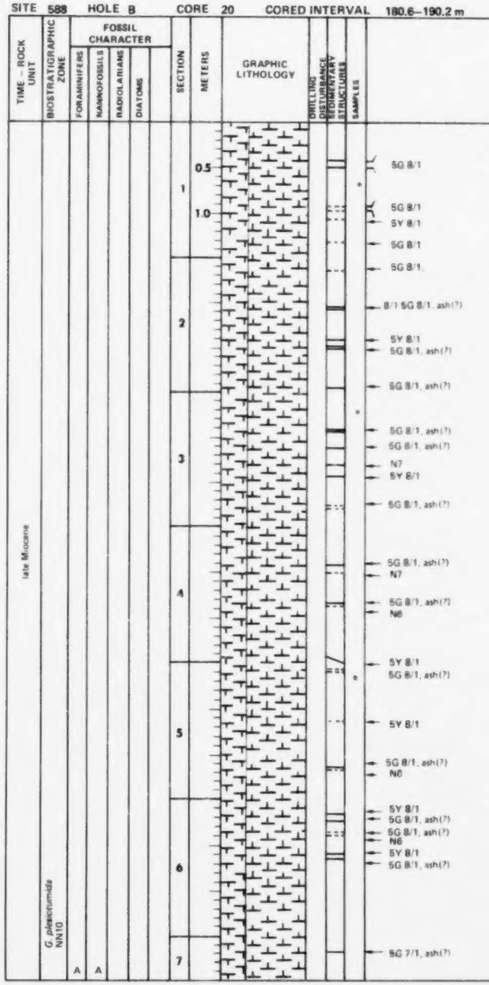
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8). Light yellowish gray (N8–5Y 8/1) burrows and laminae. Medium gray (N4 to N6) laminae of iron sulfide along the core. Light greenish gray (N8–5GY 8/1) laminae.

SMEAR SLIDE SUMMARY:

	1, 65	2, 140
	D	M
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Quartz	T	–
Heavy minerals	T	T
Pyrite	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 588 HOLE B CORE 20 CORED INTERVAL 180.6–190.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. plesiotumida
NN10
A
A
1
2
3
4
5
6
7
0.5
1.0
5G 8/1
5G 8/1
5Y 8/1
5G 8/1
5G 8/1
8/1 5G 8/1, ash(?)
5Y 8/1
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N7
5Y 8/1
5G 8/1, ash(?)
5G 8/1, ash(?)
N7
5G 8/1, ash(?)
N8
5Y 8/1
5G 8/1, ash(?)
5Y 8/1
5G 8/1, ash(?)
N8
5Y 8/1
5G 8/1, ash(?)
5G 8/1, ash(?)
N8
5Y 8/1
5G 8/1, ash(?)
5G 7/1, ash(?)

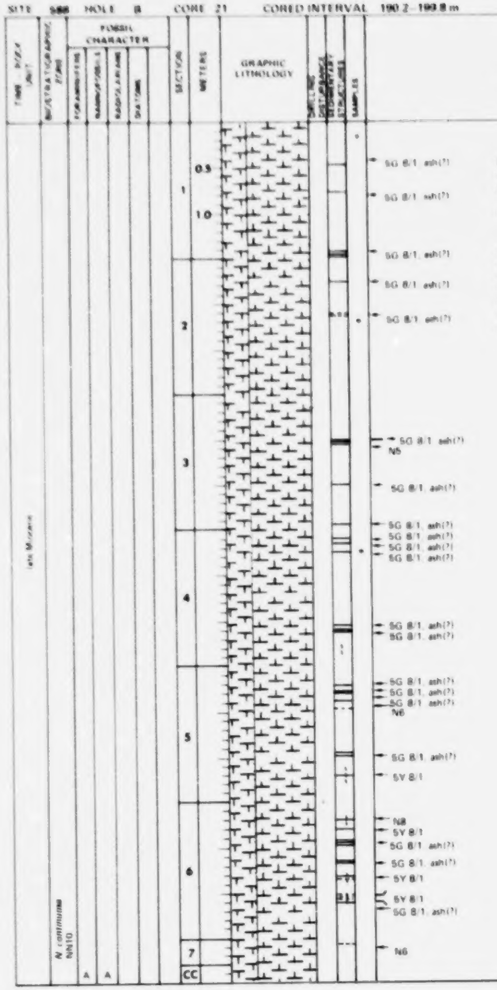
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, abundant burrows throughout, a series of green (5G 8/1) ash(?) laminae occur, iron sulfide occurs as pockets, blebs, and as burrow linings.

SMEAR SLIDE SUMMARY:

	1, 71	3, 20	5, 20
	D	D	D
Composition:			
Heavy minerals	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	A	D	D

SITE 588 HOLE B CORE 21 CORED INTERVAL 190.2–199.8 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N continuous
NN10
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N5
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N6
5G 8/1, ash(?)
5Y 8/1
N8
5Y 8/1
5G 8/1, ash(?)
5G 8/1, ash(?)
5Y 8/1
5Y 8/1
5G 8/1, ash(?)
N6

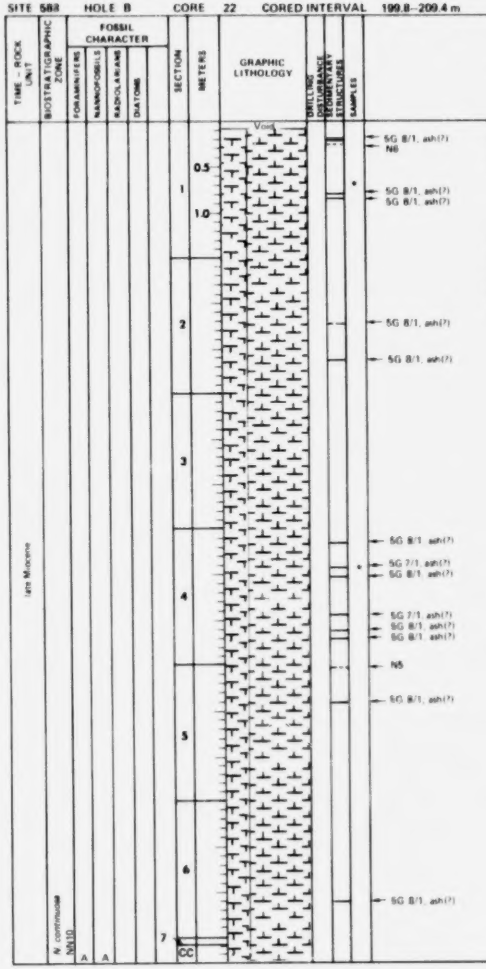
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, abundant pyrite and ash(?) laminations. Pyrite also occurs in streaks, blebs, and in burrows.

SMEAR SLIDE SUMMARY

	1, 18	2, 64	4, 23
	M	D	M
Composition:			
Quartz	–	–	T
Feldspar	–	–	T
Volcanic glass	–	–	R
Pyrite	A	–	–
Foraminifers	C	C	C
Calc. nannofossils	A	A	A

SITE 588 HOLE B CORE 22 CORED INTERVAL 199.8–209.4 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N continuous
NN10
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5G 8/1, ash(?)
N6
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 7/1, ash(?)
5G 8/1, ash(?)
5G 7/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N5
5G 8/1, ash(?)
5G 8/1, ash(?)

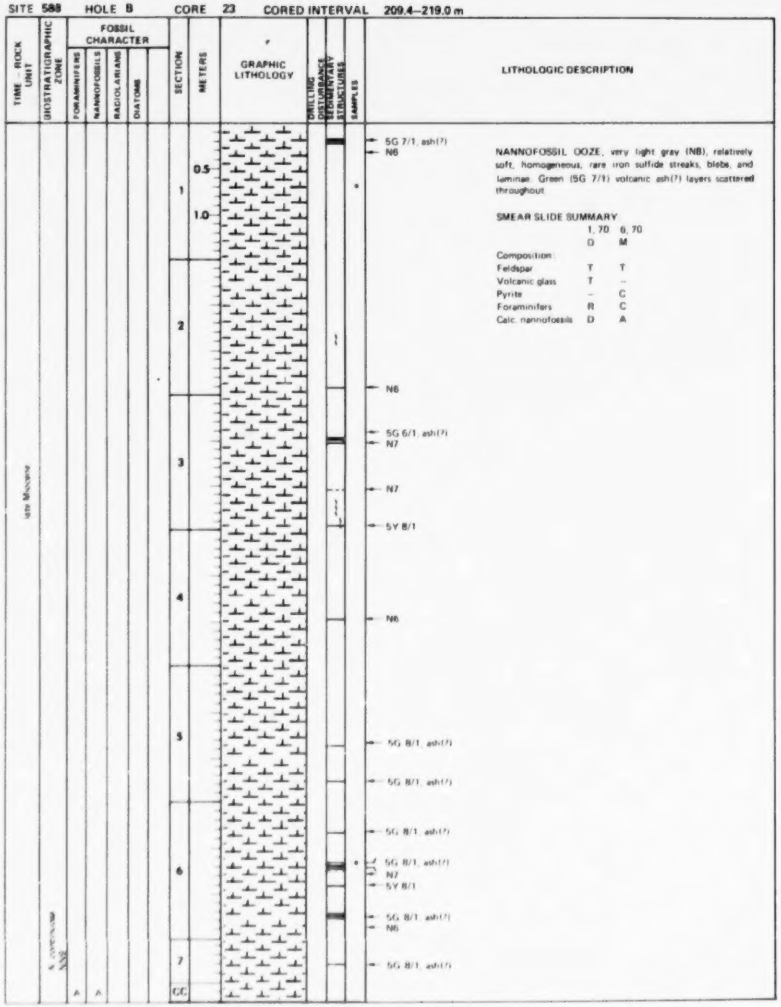
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, rare streaks, blebs, and burrow fillings of pyrite, common green (5G 8/1) ash(?) layers.

SMEAR SLIDE SUMMARY:

	1, 70	4, 47
	D	M
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	T	T
Pyrite	–	R
Foraminifers	C	C
Calc. nannofossils	A	A

SITE 588 HOLE B CORE 23 CORED INTERVAL 209.4–219.0 m

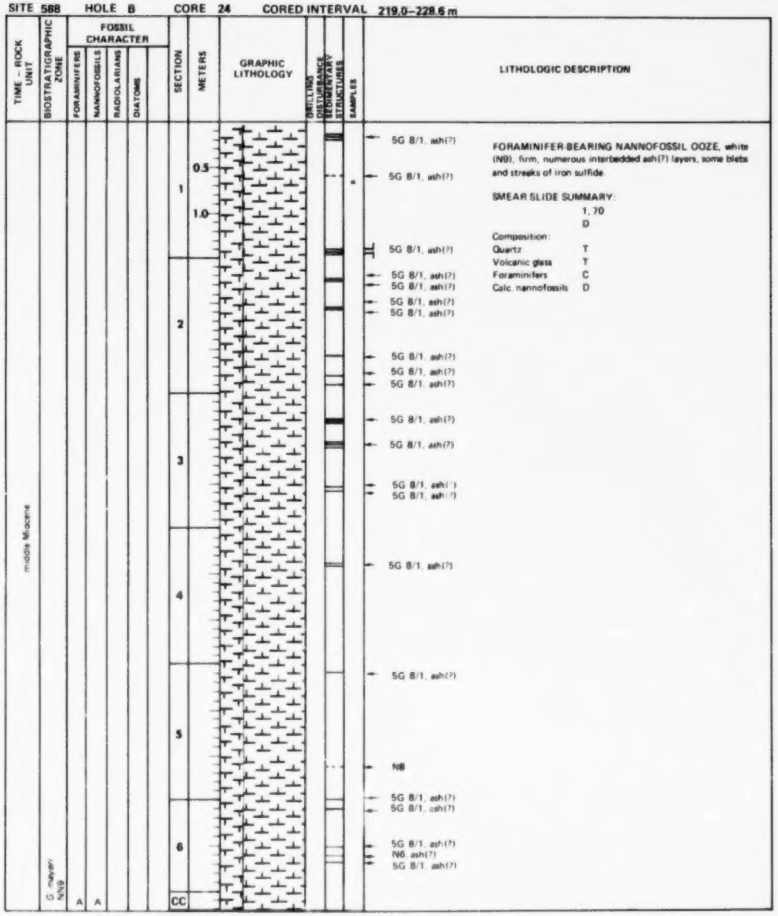

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N. continuosa
NN8
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 7/1, ash(?)
N6
N6
5G 6/1, ash(?)
N7
N7
5Y 8/1
N6
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N7
5Y 8/1
5G 8/1, ash(?)
N6
5G 8/1, ash(?)

NANNOFOSSIL OOZE, very light gray (N8), relatively soft, homogeneous, rare iron sulfide streaks, blebs, and laminae. Green (5G 7/1) volcanic ash(?) layers scattered throughout.

SMEAR SLIDE SUMMARY

	1, 70 D	6, 70 M
Composition:		
Feldspar	T	T
Volcanic glass	T	–
Pyrite	–	C
Foraminifers	R	C
Calc. nannofossils	D	A

SITE 588 HOLE B CORE 24 CORED INTERVAL 219.0–228.6 m

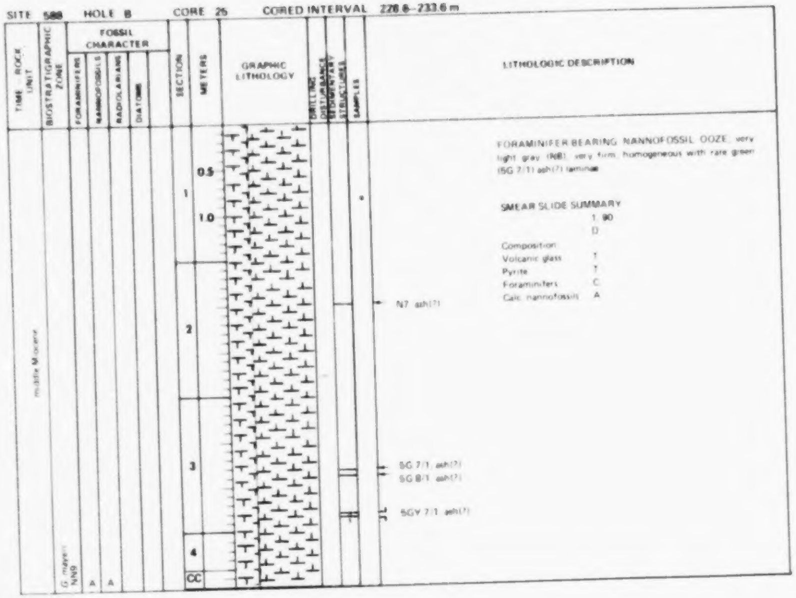

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri
NN9
A
A
1
2
3
4
5
6
CC
0.5
1.0
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N8
5G 8/1, ash(?)
5G 8/1, ash(?)
5G 8/1, ash(?)
N6, ash(?)
5G 8/1, ash(?)

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9), firm, numerous interbedded ash(?) layers, some blebs and streaks of iron sulfide.

SMEAR SLIDE SUMMARY:

	1, 70 D
Composition:	
Quartz	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 25 CORED INTERVAL 228.6–233.6 m

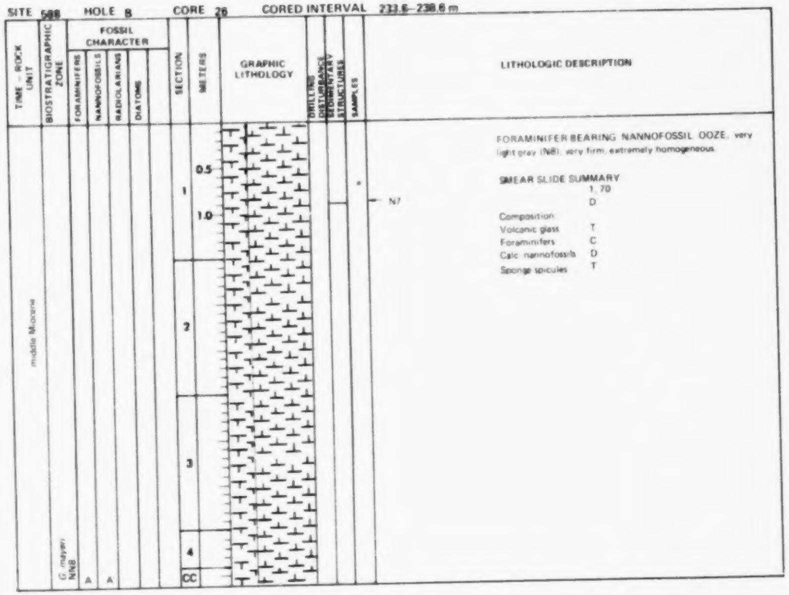

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN9
A
A
1
2
3
4
CC
0.5
1.0
*
N7 ash(?)
5G 7/1, ash(?)
5G 8/1, ash(?)
5GY 7/1 ash(?)

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), very firm, homogeneous with rare green (5G 7/1) ash(?) laminae

SMEAR SLIDE SUMMARY

	1, 90
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	C
Calc. nannofossil	A

SITE 588 HOLE B CORE 26 CORED INTERVAL 233.6–238.6 m

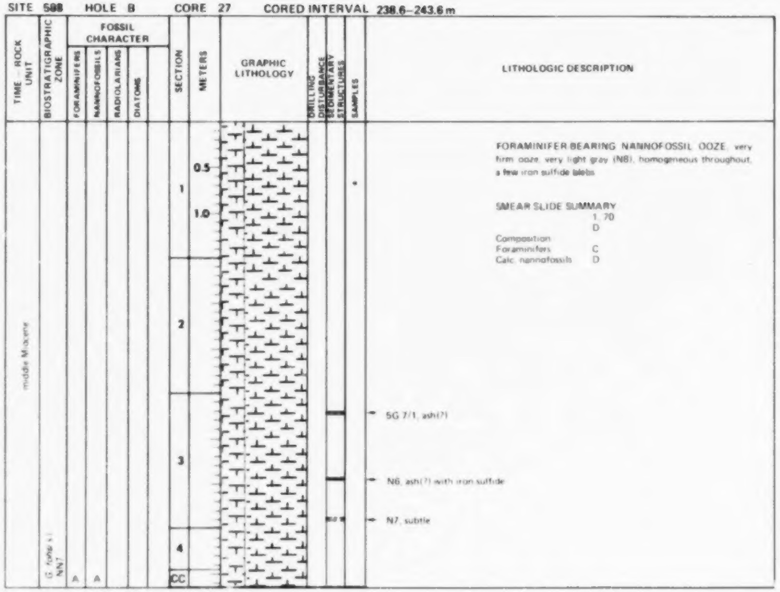

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN8
A
A
1
2
3
4
CC
0.5
1.0
*
N7

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), very firm, extremely homogeneous

SMEAR SLIDE SUMMARY

	1, 70
	D
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 588 HOLE B CORE 27 CORED INTERVAL 238.6–243.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. fohsi s.l.
NN7
A
A
1
2
3
4
CC
0.5
1.0

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very firm ooze, very light gray (N8), homogeneous throughout, a few iron sulfide blebs

SMEAR SLIDE SUMMARY

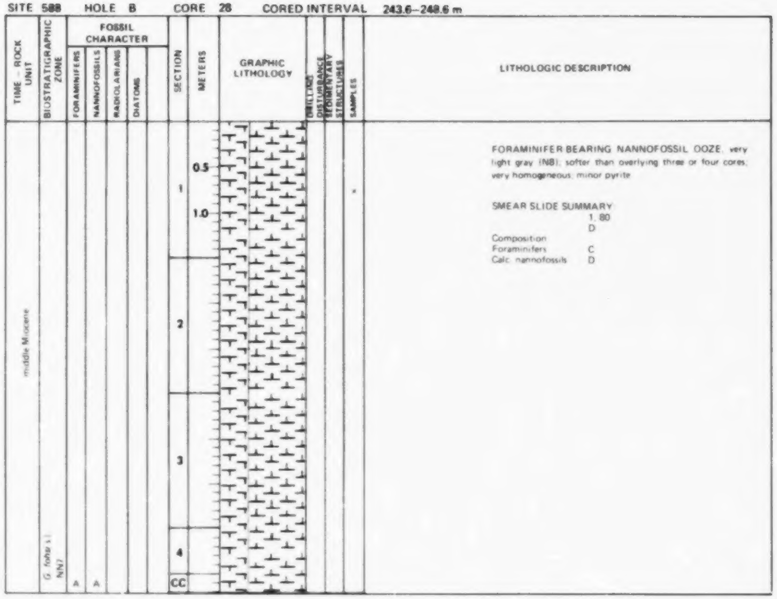
	1, 70
	D
Composition	
Foraminifers	C
Calc. nannofossils	D

5G 7/1, ash(?)

N6, ash(?) with iron sulfide

N7, subtle

SITE 588 HOLE B CORE 28 CORED INTERVAL 243.6–248.6 m

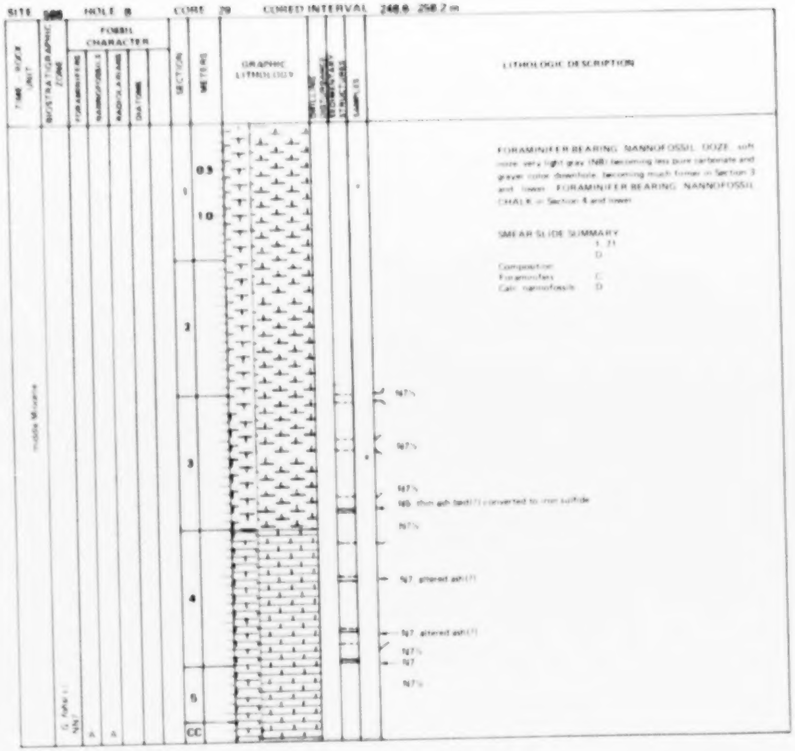

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. fohsi s.l.
NN7
A
A
1
2
3
4
CC
0.5
1.0

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8); softer than overlying three or four cores; very homogeneous; minor pyrite

SMEAR SLIDE SUMMARY

	1, 80
	D
Composition	
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 29 CORED INTERVAL 248.8–258.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN7
A
A
0.5
1.0
1
2
3
4
5
CC
N7½
N7½
N7½
N6 thin ash bed(?) converted to iron sulfide
N7½
N7 altered ash(?)
N7 altered ash(?)
N7½
N7
N7½

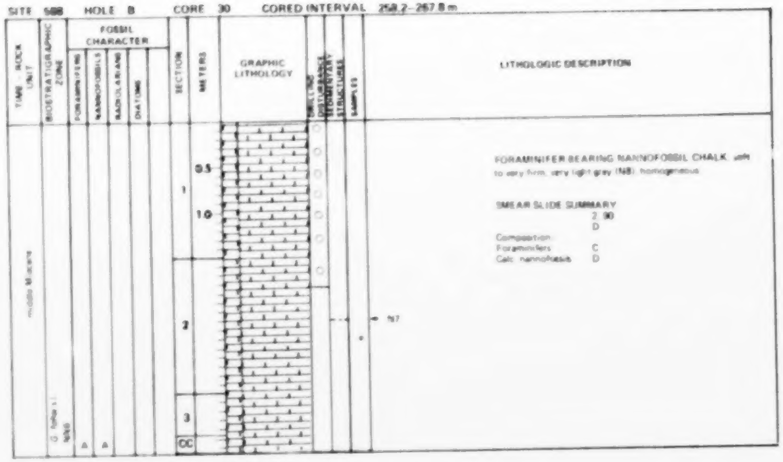
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft ooze, very light gray (N8) becoming less pure carbonate and grayer color downhole, becoming much firmer in Section 3 and lower. FORAMINIFER-BEARING NANNOFOSSIL CHALK in Section 4 and lower.

SMEAR SLIDE SUMMARY

	1, 21
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 30 CORED INTERVAL 258.2–267.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
0.5
1.0
1
2
3
CC
N7

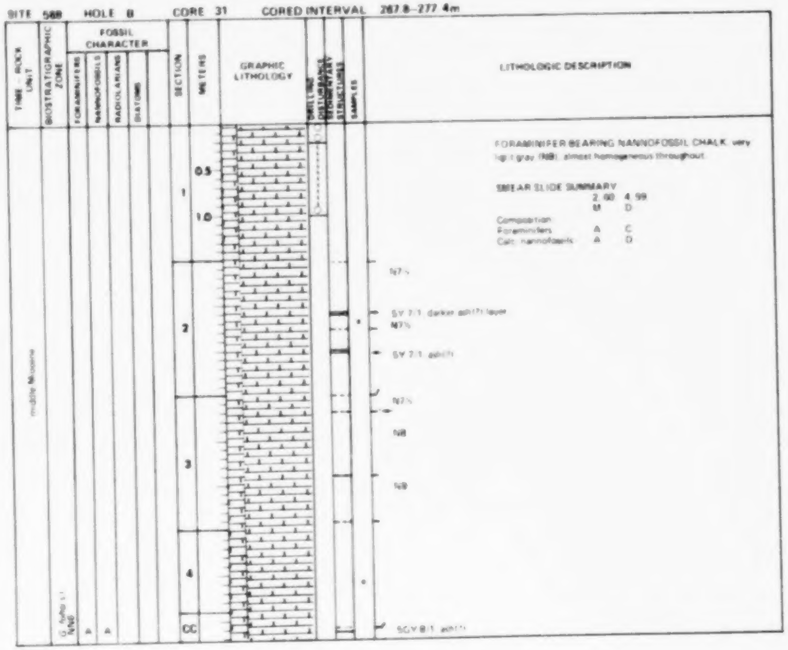
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, soft to very firm, very light gray (N8), homogeneous.

SMEAR SLIDE SUMMARY

	2, 90
	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE B CORE 31 CORED INTERVAL 267.8–277.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
0.5
1.0
1
2
3
4
CC
N7½
5Y 7/1 darker ash(?) layer
N7½
5Y 7/1 ash(?)
N7½
N8
N8
5GY 8/1 ash(?)

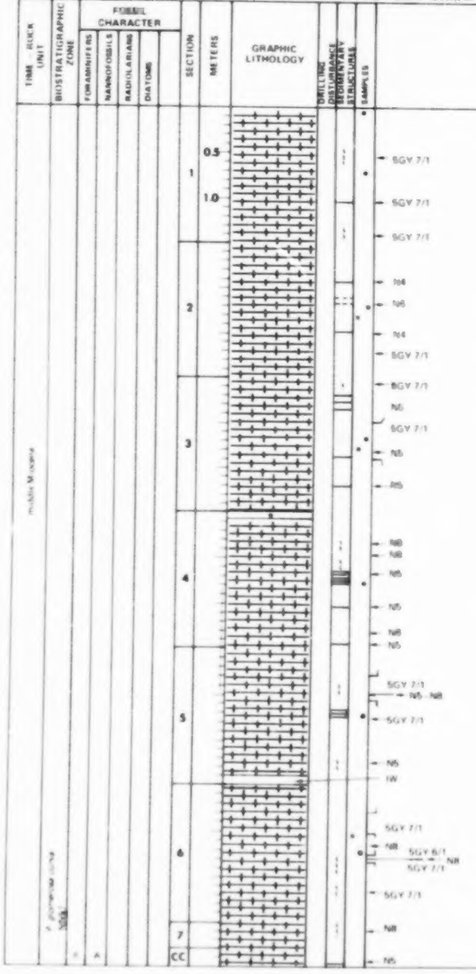
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), almost homogeneous throughout.

SMEAR SLIDE SUMMARY

	2, 60	4, 99
	M	D
Composition:		
Foraminifers	A	C
Calc. nannofossils	A	D

SITE 588 HOLE C CORE 1 CORED INTERVAL 305.7–315.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN5
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 7/1
N4
N5
N6
N8
N5–N8
5GY 6/1
N9

LITHOLOGIC DESCRIPTION

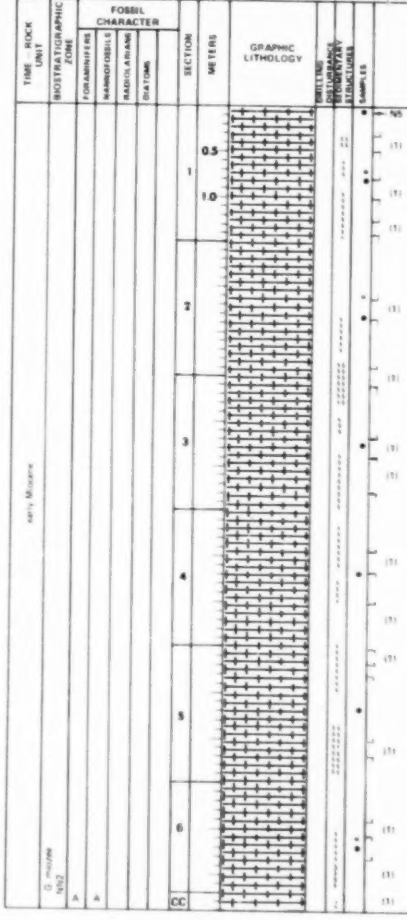
FORAMINIFER NANNOFOSSIL CHALK, light greenish gray (5GY 8/1 to 5GY 7/1). Greenish gray (5GY 7/1) and light gray (N8) burrows and laminae. Medium gray (N4–N6) burrows and laminae. *Zoophycos*-like burrows (N4). Possible *Chondrites* along the core.

*Gap due to drilling.

SMEAR SLIDE SUMMARY

	2, 80 D	3, 75	6, 66
Texture			
Sand	T	T	T
Silt	C	C	A
Clay	D	D	A
Composition			
Quartz	T	–	T
Feldspar	–	–	T
Mica	–	–	T
Heavy minerals	T	T	T
Volcanic glass	–	R	–
Pyrite	–	–	T
Foraminifers	A	A	A
Calc. nannofossils	A	A	A

SITE 588 HOLE C CORE 2 CORED INTERVAL 315.3–324.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. mayeri
NN2
A
A
0.5
1.0
1
2
3
4
5
6
CC
N5
(1)

LITHOLOGIC DESCRIPTION

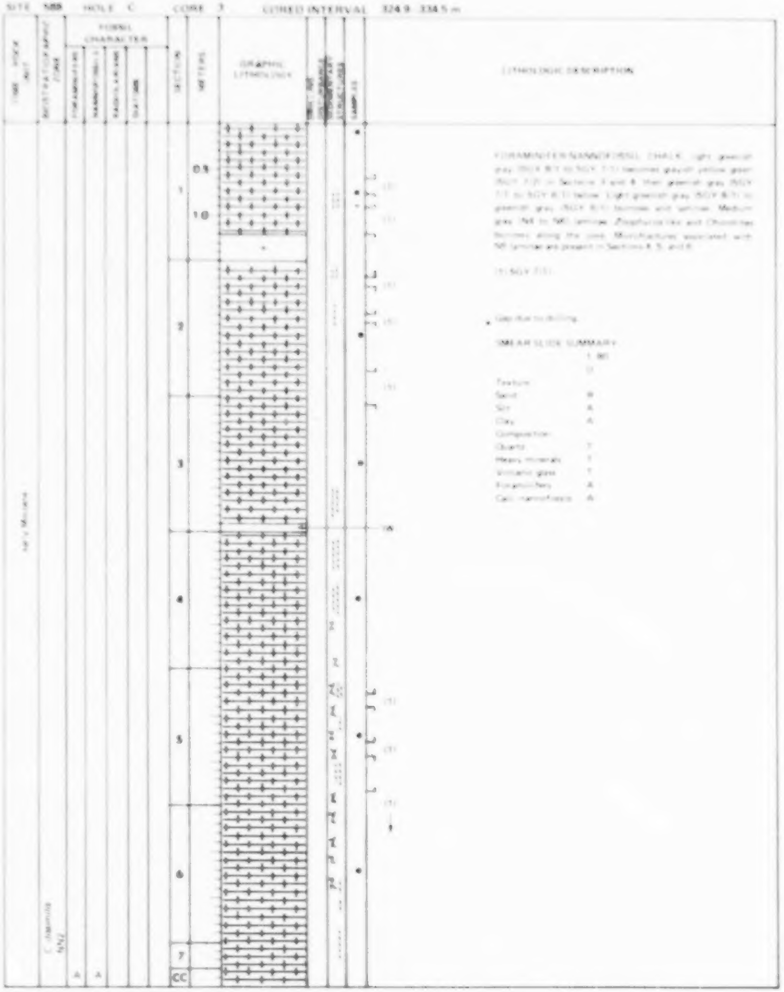
FORAMINIFER NANNOFOSSIL CHALK, light greenish gray (5GY 8/1 to 5GY 7/1). Greenish gray (5GY 7/1, 5GY 6/1) and light greenish gray (5GY 8/1) burrows and laminae. Medium gray (N4–N6) laminae. *Zoophycos*-like and *Chondrites* burrows along the core.

(1) 5GY 7/1 levels.

SMEAR SLIDE SUMMARY

	1, 74 D	2, 90 D	6, 83 D
Texture			
Sand	–	R	–
Silt	A	A	–
Clay	A	A	–
Composition			
Heavy minerals	T	T	T
Pyrite	T	T	T
Foraminifers	A	A	A
Calc. nannofossils	A	A	A

SITE 588 HOLE C CORE 3 CORED INTERVAL 324.9–334.5 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
C. abisectus
NN2
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

FORAMINIFER-NANNOFOSSIL CHALK, light greenish gray (5GY 8/1 to 5GY 7/1) becomes grayish yellow green (5GY 7/2) in Sections 3 and 4, then greenish gray (5GY 7/1 to 5GY 6/1) below. Light greenish gray (5GY 8/1) to greenish gray (5GY 6/1) burrows and laminae. Medium gray (N4 to N6) laminae. *Zoophycos*-like and *Chondrites* burrows along the core. Microfractures associated with N6 laminae are present in Sections 4, 5, and 6.

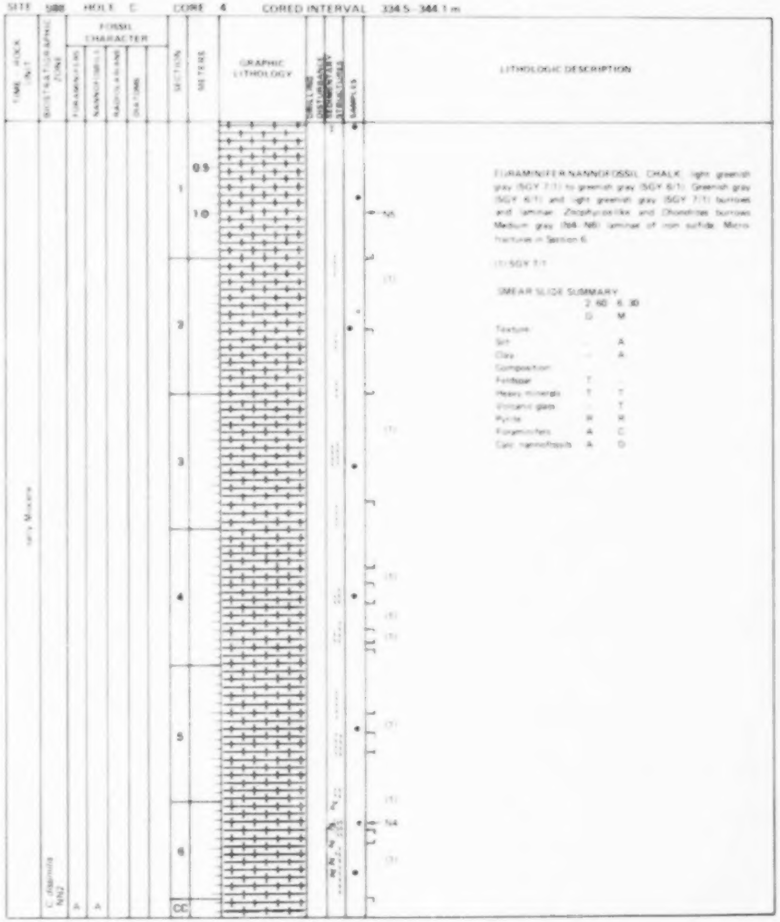
(1) 5GY 7/1

* Gap due to drilling

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture:	
Sand	R
Silt	A
Clay	A
Composition:	
Quartz	T
Heavy minerals	T
Volcanic glass	T
Foraminifers	A
Calc. nannofossils	A

SITE 588 HOLE C CORE 4 CORED INTERVAL 334.5–344.1 m

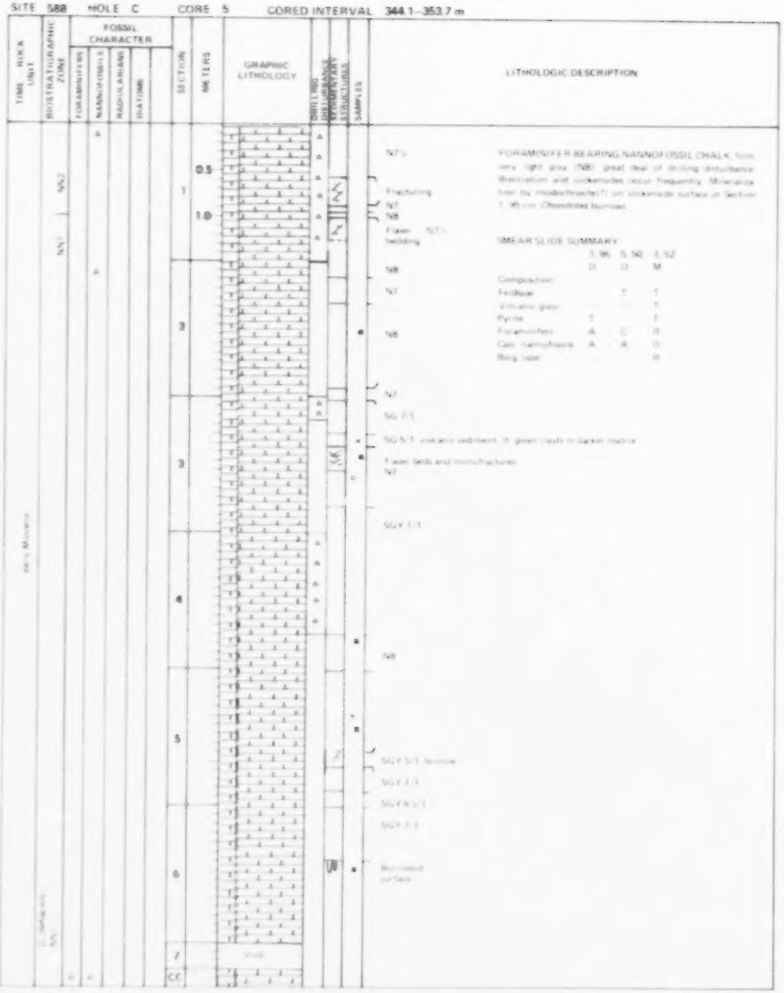

TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
C. abisectus
NN2
A
A
0.5
1.0
1
2
3
4
5
6
CC
N6
N4

FORAMINIFER-NANNOFOSSIL CHALK, light greenish gray (5GY 7/1) to greenish gray (5GY 6/1). Greenish gray (5GY 6/1) and light greenish gray (5GY 7/1) burrows and laminae. *Zoophycos*-like and *Chondrites* burrows. Medium gray (N4–N6) laminae of iron sulfide. Microfractures in Section 6.

(1) 5GY 7/1

SMEAR SLIDE SUMMARY

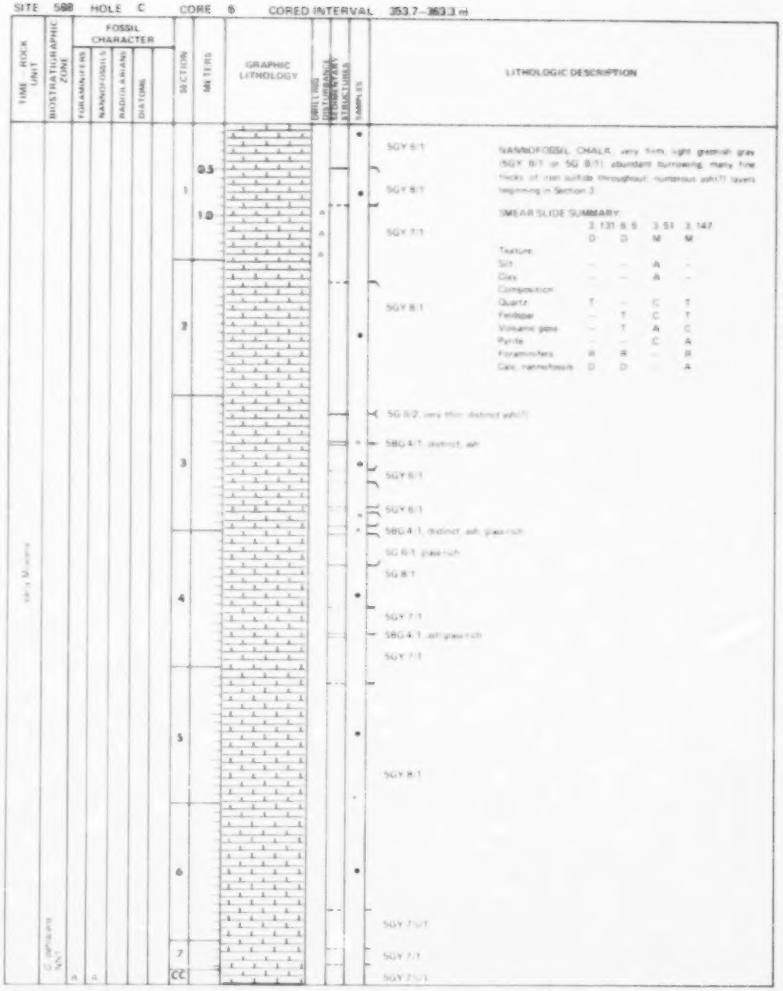
	2, 60	6, 30
	D	M
Texture:		
Silt	–	A
Clay	–	A
Composition:		
Feldspar	T	–
Heavy minerals	T	T
Volcanic glass	–	T
Pyrite	R	R
Foraminifers	A	C
Calc. nannofossils	A	D


SITE 588 HOLE C CORE 5 CORED INTERVAL 344.1–353.7 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
NN2
NN1
C. abisectus NN1
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7/5
Fracturing
N7
N8
Flaser N7/5 bedding
N8
N7
N8
N7
5G 7/1
5G 5/1 volcanic sediment, lt. green clasts in darker matrix
Flaser beds and microfractures
N7
5GY 7/1
N8
5GY 5/1 laminae
5GY 7/1
5GY 8.5/1
5GY 7/1
Burrowed surface

FORAMINIFER BEARING NANNOFOSSIL CHALK, firm, very light gray (N8); great deal of drilling disturbance. Brecciation and slickensides occur frequently. Mineralization by rhodochrosite(?) on slickenside surface at Section 1, 95 cm. Chondrites burrows.

SMEAR SLIDE SUMMARY

	1, 96	5, 90	3, 52
	D	D	M
Composition:			
Feldspar		T	T
Volcanic glass	—	—	T
Pyrite	T		T
Foraminifers	A	C	R
Calc. nannofossils	A	A	D
Biog. opal	—		R

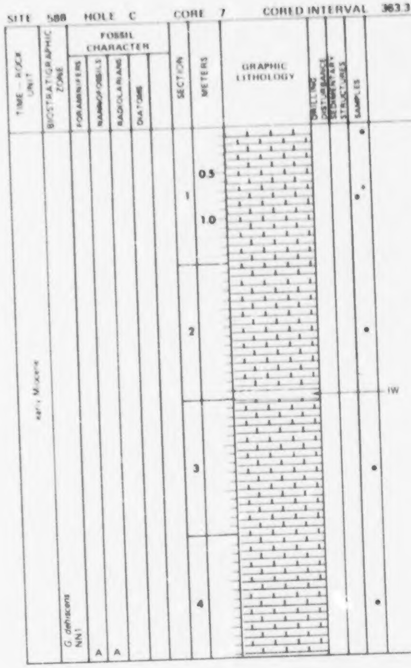

SITE 588 HOLE C CORE 6 CORED INTERVAL 353.7–363.3 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
C. abisectus NN1
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 6/1
5GY 8/1
5GY 7/1
5GY 8/1
5G 6/2, very thin distinct ash(?)
5BG 4/1, distinct, ash
5GY 6/1
5GY 6/1
5BG 4/1, distinct, ash, glass-rich
5G 6/1, glass-rich
5G 8/1
5GY 7/1
5BG 4/1, ash glass-rich
5GY 7/1
5GY 8/1
5GY 7.5/1
5GY 7/1
5GY 7.5/1

NANNOFOSSIL CHALK, very firm, light greenish gray (5GY 8/1 or 5G 8/1); abundant burrowing, many fine flecks of iron sulfide throughout; numerous ash(?) layers beginning in Section 3.

SMEAR SLIDE SUMMARY

	3, 131	6, 5	3, 51	3, 147
	D	D	M	M
Texture:				
Silt	—	—	A	—
Clay	—	—	A	—
Composition:				
Quartz	T	—	C	T
Feldspar	—	T	C	T
Volcanic glass	—	T	A	C
Pyrite	—	—	C	A
Foraminifers	R	R	—	R
Calc. nannofossils	D	D	—	A

SITE 588 HOLE C CORE 7 CORED INTERVAL 363.3–372.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. dehiscens
NN1
A
A
1
2
3
4
0.5
1.0
IW

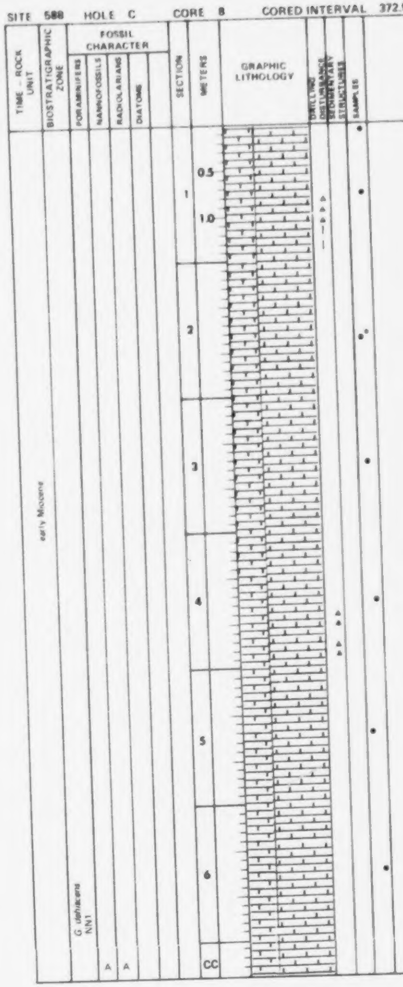
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very firm, light greenish gray (5GY 8/1), no more ash layers throughout entire core; extremely homogeneous throughout except for burrows.

SMEAR SLIDE SUMMARY

	1, 70
	D
Composition	
Feldspar	T
Foraminifers	R
Calc. nannofossils	D

SITE 588 HOLE C CORE 8 CORED INTERVAL 372.9–382.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. dehiscens
NN1
A
A
1
2
3
4
5
6
CC
0.5
1.0

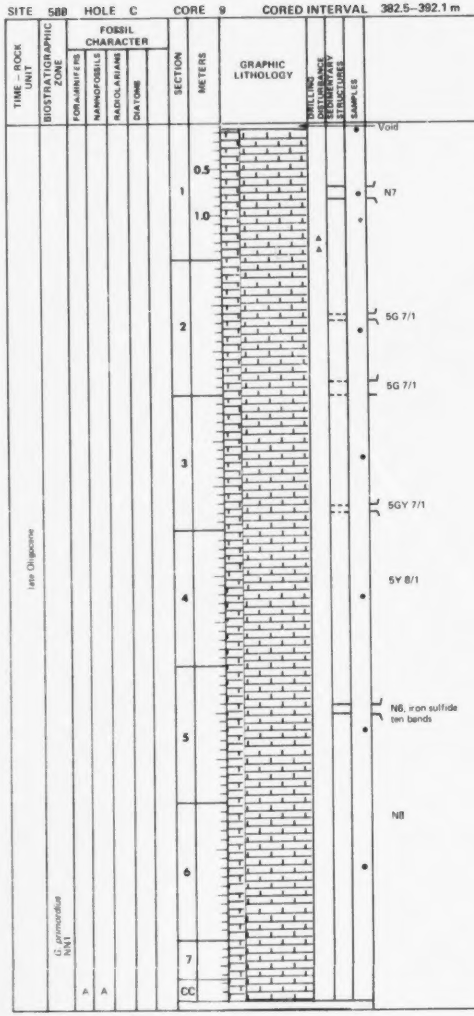
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very firm, light gray (N7); moderate amount of burrowing, minor iron sulfide component, no obvious bedding.

SMEAR SLIDE SUMMARY

	2, 70
	D
Composition	
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE C CORE 9 CORED INTERVAL 382.5–392.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. primordius
NN1
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7
5G 7/1
5G 7/1
5GY 7/1
5Y 8/1
N6, iron sulfide
ten bands
N8

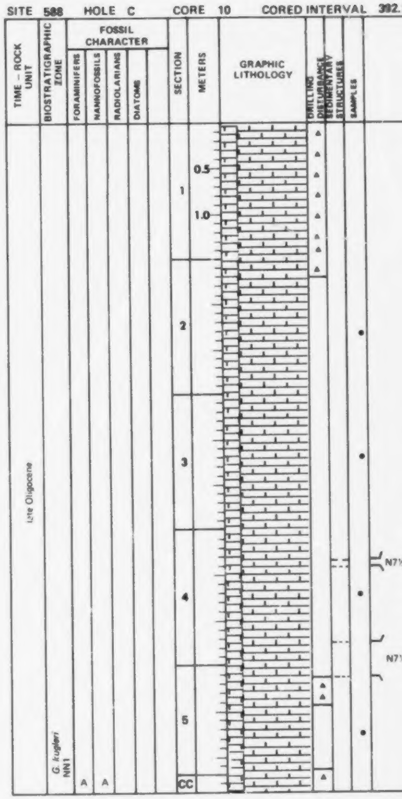
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very firm, very light gray (N8), abundant burrows – many *Zoophycos*; very slight greenish hue throughout (glass?).

SMEAR SLIDE SUMMARY:

	1, 107 D
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 588 HOLE C CORE 10 CORED INTERVAL 392.1–401.7 m

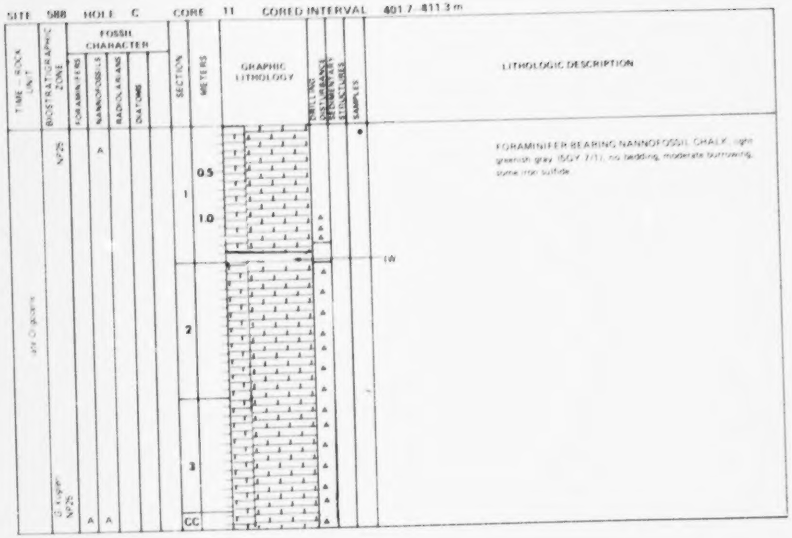

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. kugleri
NN1
A
A
0.5
1.0
1
2
3
4
5
CC
N7½
N7½

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), moderate burrowing, otherwise homogeneous.

SMEAR SLIDE SUMMARY:

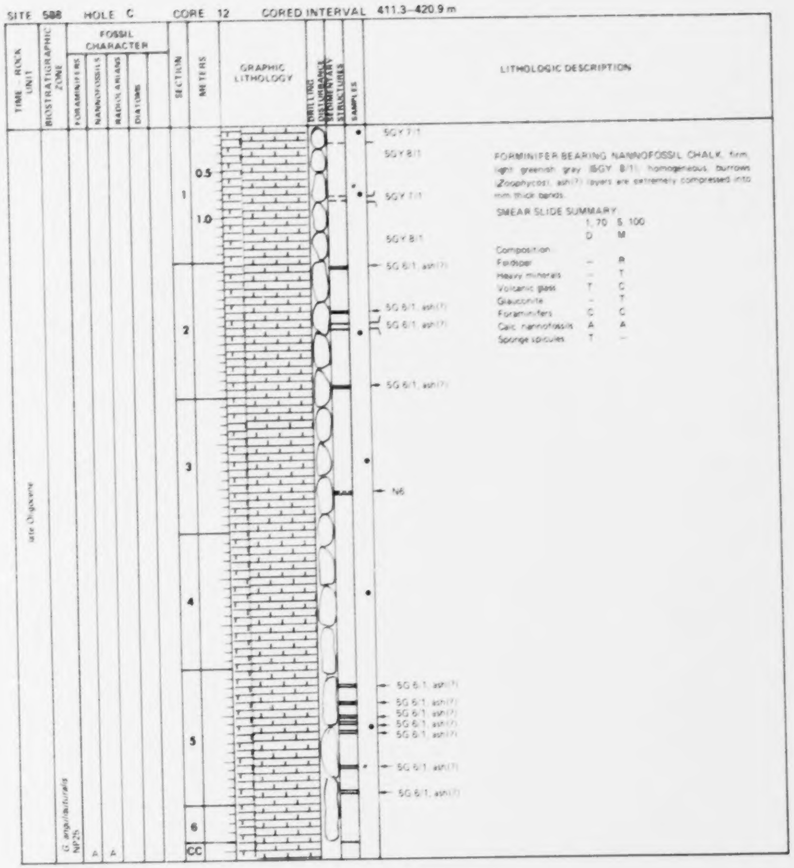
	2, 70 D
Composition:	
Feldspar	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D



SITE 588 HOLE C CORE 11 CORED INTERVAL 401.7–411.3 m

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Oligocene
NP25
A
0.5
1
1.0
2
3
CC
G. kugleri
NP25
A
A
IW

FORAMINIFER BEARING NANNOFOSSIL CHALK, light greenish gray (5GY 7/1), no bedding, moderate burrowing, some iron sulfide.



SITE 588 HOLE C CORE 12 CORED INTERVAL 411.3–420.9 m

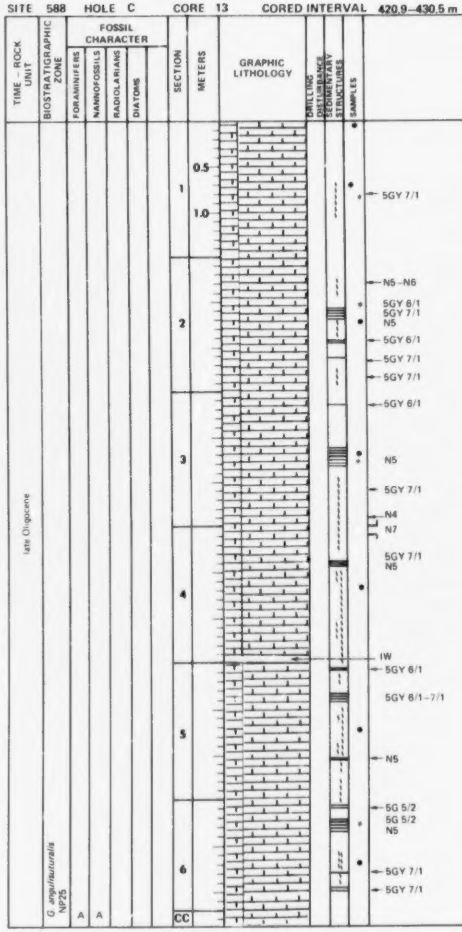
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Oligocene
0.5
1
1.0
2
3
4
5
6
CC
G. angulisuturalis
NP25
A
A
5GY 7/1
5GY 8/1
5GY 7/1
5GY 8/1
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
N6
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)
5G 6/1, ash(?)

FORMINIFER BEARING NANNOFOSSIL CHALK, firm, light greenish gray (5GY 8/1), homogeneous, burrows (Zoophycos), ash(?) layers are extremely compressed into mm thick bands.

SMEAR SLIDE SUMMARY

	1, 70	5, 100
	D	M
Composition:		
Feldspar	—	R
Heavy minerals	—	T
Volcanic glass	T	C
Glauconite	—	T
Foraminifers	C	C
Calc. nannofossils	A	A
Sponge spicules	T	—

SITE 588 HOLE C CORE 13 CORED INTERVAL 420.9–430.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. angulisuturalis
NP25
A
A
1
2
3
4
5
6
CC
0.5
1.0
5GY 7/1
N5–N6
5GY 6/1
5GY 7/1
N5
5GY 6/1
5GY 7/1
5GY 7/1
5GY 6/1
N5
5GY 7/1
N4
N7
5GY 7/1
N5
IW
5GY 6/1
5GY 6/1–7/1
N5
5G 5/2
5G 5/2
N5
5GY 7/1
5GY 7/1

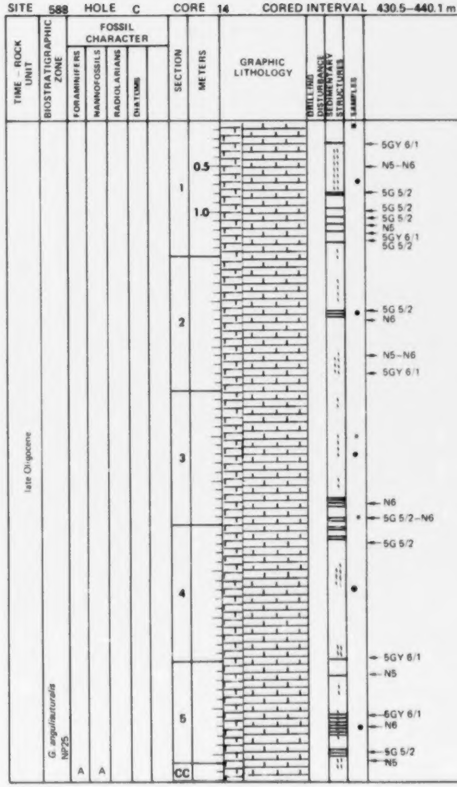
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, homogeneous, light greenish gray (5GY 8/1). Greenish gray (5GY 7/1, 5GY 6/1, 5G 5/2) burrows and laminae. *Zoophycos*-like burrows and *Chondrites* along the core. Medium gray (N4–N6) burrows and laminae.

SMEAR SLIDE SUMMARY

	1, 80 D	2, 50 M	2, 61 M	3, 75 M	6, 29 M
Texture:					
Silt	–	–	–	A	C
Clay	–	–	–	A	D
Composition:					
Quartz	–	T	T	–	–
Feldspar	–	–	T	–	–
Heavy minerals	T	–	–	T	–
Volcanic glass	–	T	T	–	–
Pyrite	–	C	R	R	–
Foraminifers	C	A	C	C	C
Calc. nannofossils	A	A	D	D	D
Sponge spicules	–	–	R	–	–

SITE 588 HOLE C CORE 14 CORED INTERVAL 430.5–440.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. angulisuturalis
NP25
A
A
1
2
3
4
5
CC
0.5
1.0
5GY 6/1
N5–N6
5G 5/2
5G 5/2
5G 5/2
N5
5GY 6/1
5G 5/2
5G 5/2
N6
N5–N6
5GY 6/1
N6
5G 5/2–N6
5G 5/2
5GY 6/1
N5
5GY 6/1
N6
5G 5/2
N5

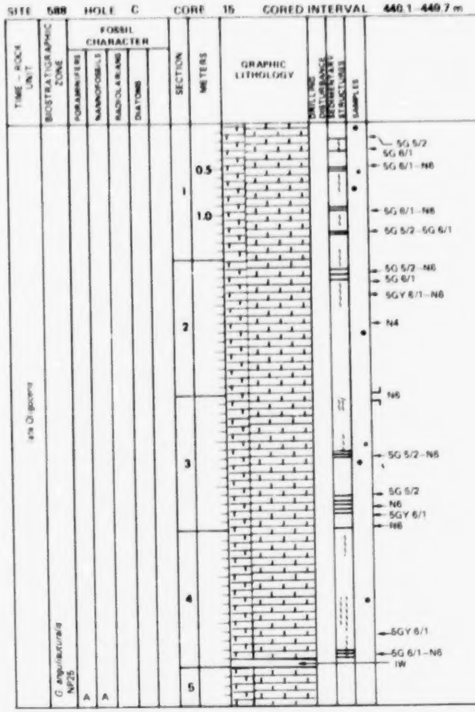
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK, light greenish gray (5GY 7/1). Greenish gray (5GY 8/1, 5GY 6/1, 5G 5/2) burrows and laminae. Medium gray (N4–N6) burrows and laminae. *Zoophycos*-like burrows and *Chondrites* along the core.

SMEAR SLIDE SUMMARY

	3, 60 D	3, 146 M
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Quartz	–	T
Volcanic glass	T	R
Pyrite	–	R
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	T	–

SITE 588 HOLE C CORE 15 CORED INTERVAL 440.1–449.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. angulisuturalis NP25
A
A
1
2
3
4
5
0.5
1.0
5G 5/2
5G 6/1
5G 6/1–N6
5G 6/1–N6
5G 5/2–5G 6/1
5G 5/2–N6
5G 6/1
5GY 6/1–N6
N4
N6
5G 5/2–N6
5G 5/2
N6
5GY 6/1
N6
5GY 6/1
5G 6/1–N6
IW

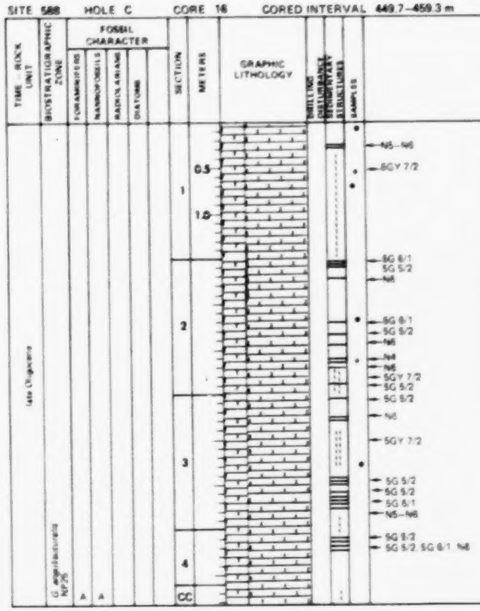
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, light greenish gray (5GY 7/1). Greenish gray (5GY 6/1, 5G 6/1, 5G 5/2) and medium gray (N4–N6) burrows and laminae. *Zoophycos*-like burrows and *Chondrites* along the core.

SMEAR SLIDE SUMMARY

	1, 70 D	3, 85 M
Texture		
Silt	C	–
Clay	D	–
Composition		
Quartz	–	T
Volcanic glass	R	–
Pyrite	R	R
Foraminifers	C	R
Calc. nannofossils	D	D
Sponge spicules	–	T

SITE 588 HOLE C CORE 16 CORED INTERVAL 449.7–459.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. angulisuturalis NP25
A
A
1
2
3
4
CC
0.5
1.0
N5–N6
5GY 7/2
5G 6/1
5G 5/2
N6
5G 6/1
5G 5/2
N6
N4
N6
5GY 7/2
5G 5/2
5G 5/2
N6
5GY 7/2
5G 5/2
5G 5/2
5G 6/1
N5–N6
5G 5/2
5G 5/2, 5G 6/1, N6

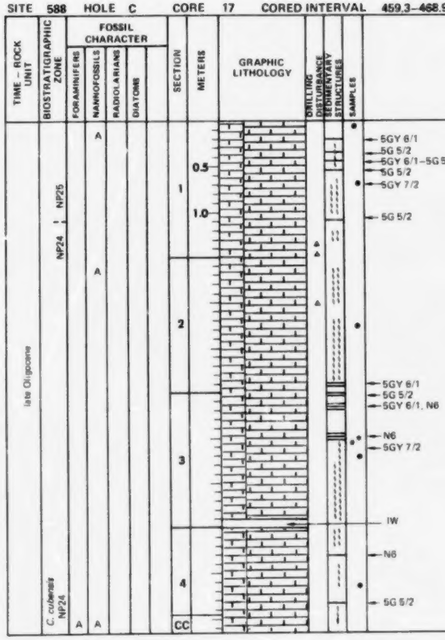
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, light greenish gray (5GY 7/1). Greenish gray (5GY 6/1, 5G 5/2), grayish yellow green (5GY 7/2) and medium gray (N4 to N6) burrows and laminae. *Zoophycos*-like burrows and *Chondrites* are present along the core.

SMEAR SLIDE SUMMARY

	1, 57 D	2, 117 M
Texture		
Silt	C	–
Clay	D	–
Composition		
Quartz	T	–
Feldspar	–	T
Volcanic glass	–	R
Pyrite	–	R
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	T	–

SITE 588 HOLE C CORE 17 CORED INTERVAL 459.3–468.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
NP24 ¦ NP25
C. cubensis NP24
A
A
A A
1
2
3
4
CC
0.5
1.0
5GY 6/1
5G 5/2
5GY 6/1–5G 5/2
5G 5/2
5GY 7/2
5G 5/2
5GY 6/1
5G 5/2
5GY 6/1, N6
N6
5GY 7/2
IW
N6
5G 5/2

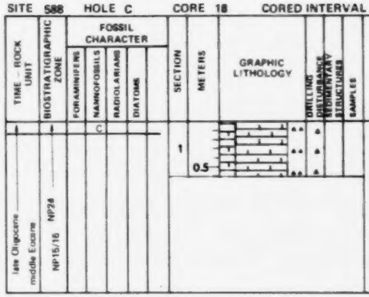
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, light greenish gray (5GY 7/1). Greenish gray (5GY 6/1, 5G 5/2), grayish yellow green (5GY 7/2) and medium gray (N4 to N6) burrows and laminae. *Zoophycos*-like burrows and *Chondrites* are present along the core.

SMEAR SLIDE SUMMARY:

	3, 65 D	3, 47 M
Texture:		
Silt	A	C
Clay	A	D
Composition:		
Feldspar	–	T
Heavy minerals	T	–
Volcanic glass	T	T
Pyrite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Silicoflagellates	T	–

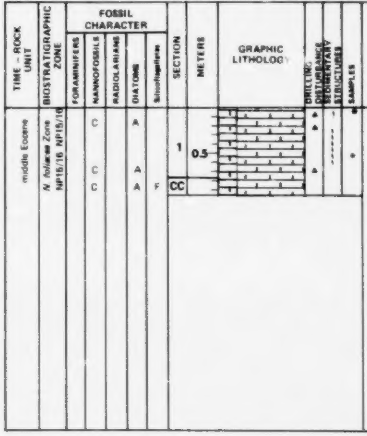
SITE 588 HOLE C CORE 18 CORED INTERVAL 468.9–478.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
middle Eocene
NP24
NP15/16
C
1
0.5

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very firm, compacted burrows, greenish-gray (5G 7/1), flaser-bedded in part and FORAMINIFER-BEARING CHERT, greenish gray (5G 7/1).

SITE 588 HOLE C CORE 19 CORED INTERVAL 478.5–488.1 m

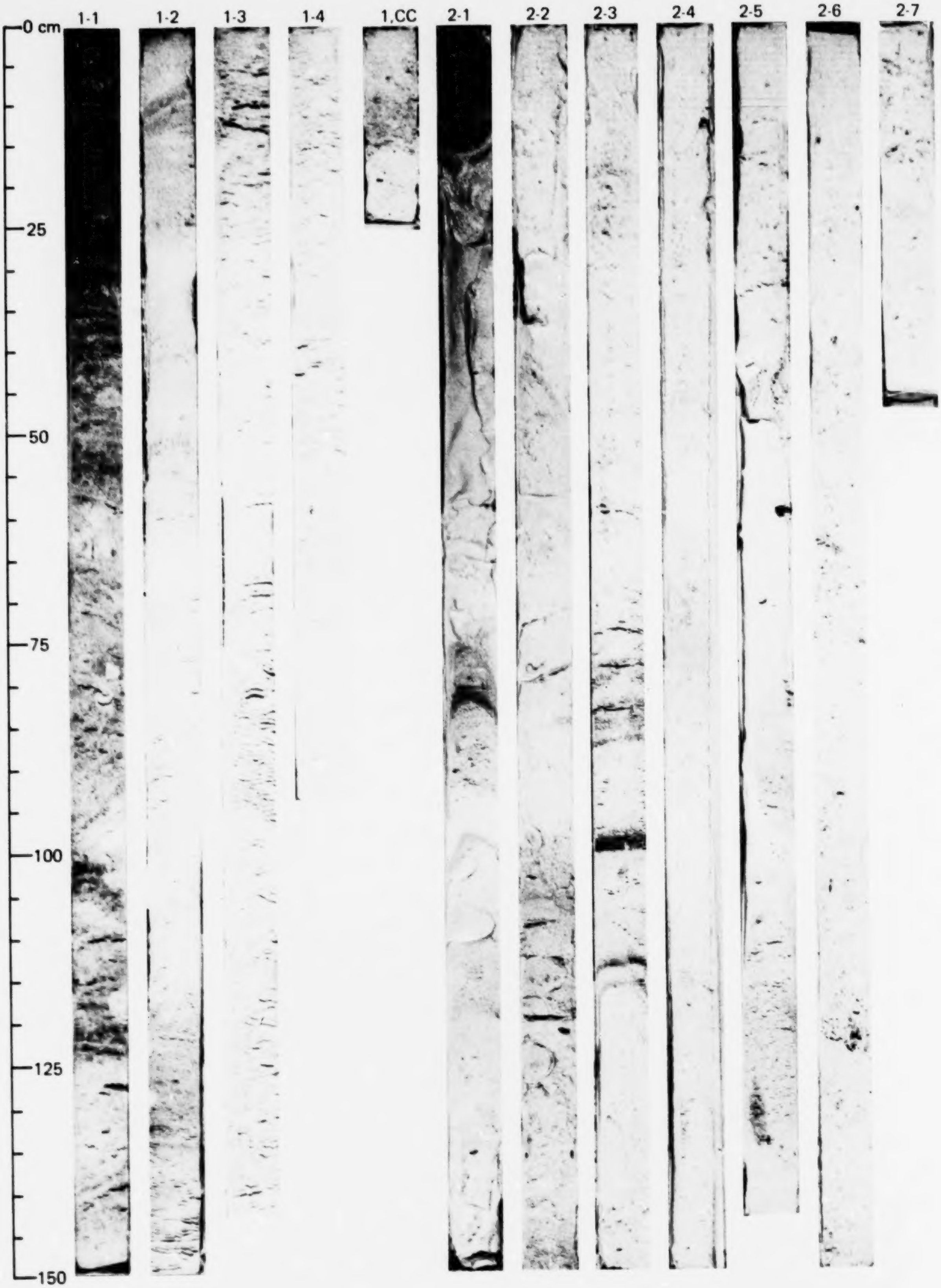

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
Silicoflagellates
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Eocene
N. foliacea Zone
NP15/16 NP15/16
C A
C A
C A F
1
CC
0.5

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, grayish yellow green (5GY 7/2) from the top to 30 cm, then light greenish gray (5GY 7/1). Yellowish gray (5Y 8/2) and grayish yellow green (5GY 7/2) burrows.

SMEAR SLIDE SUMMARY:

	1, 54 D
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R


1-1
1-2
1-3
1-4
1,CC
2-1
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2-6
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0 cm
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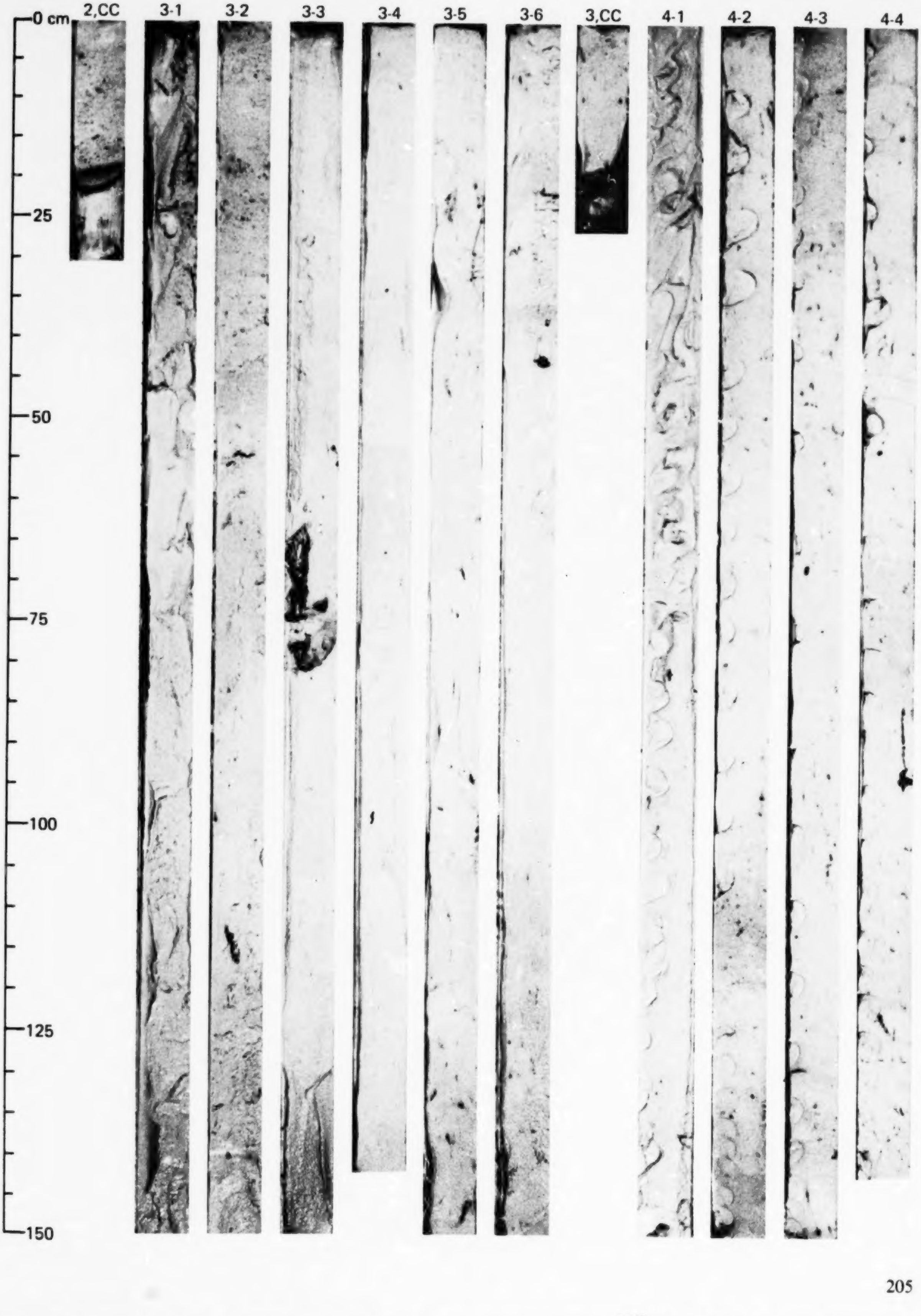
0 cm
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3,CC
4-1
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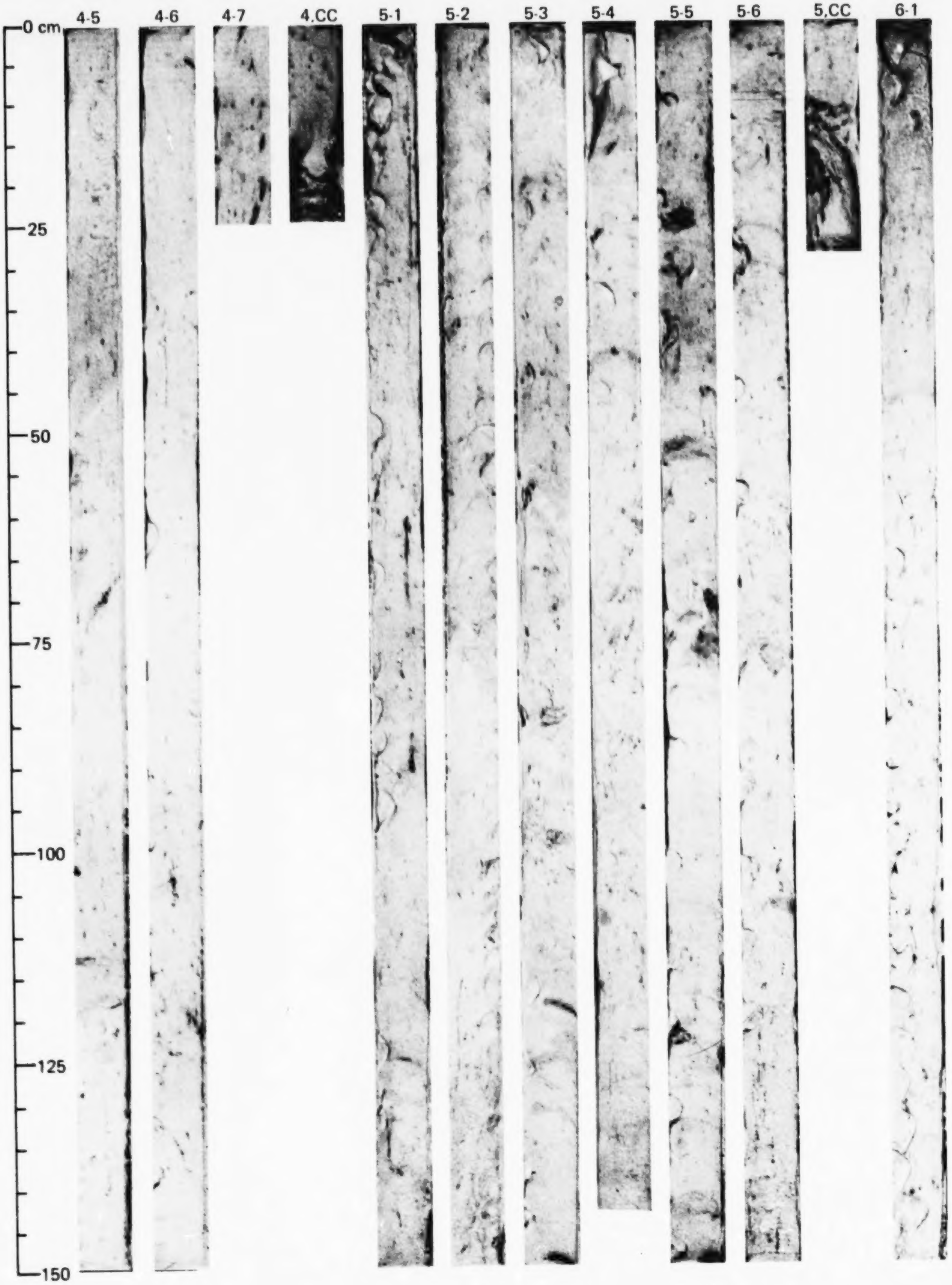
4-4


4-5
4-6
4-7
4,CC
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5-4
5-5
5-6
5,CC
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0 cm
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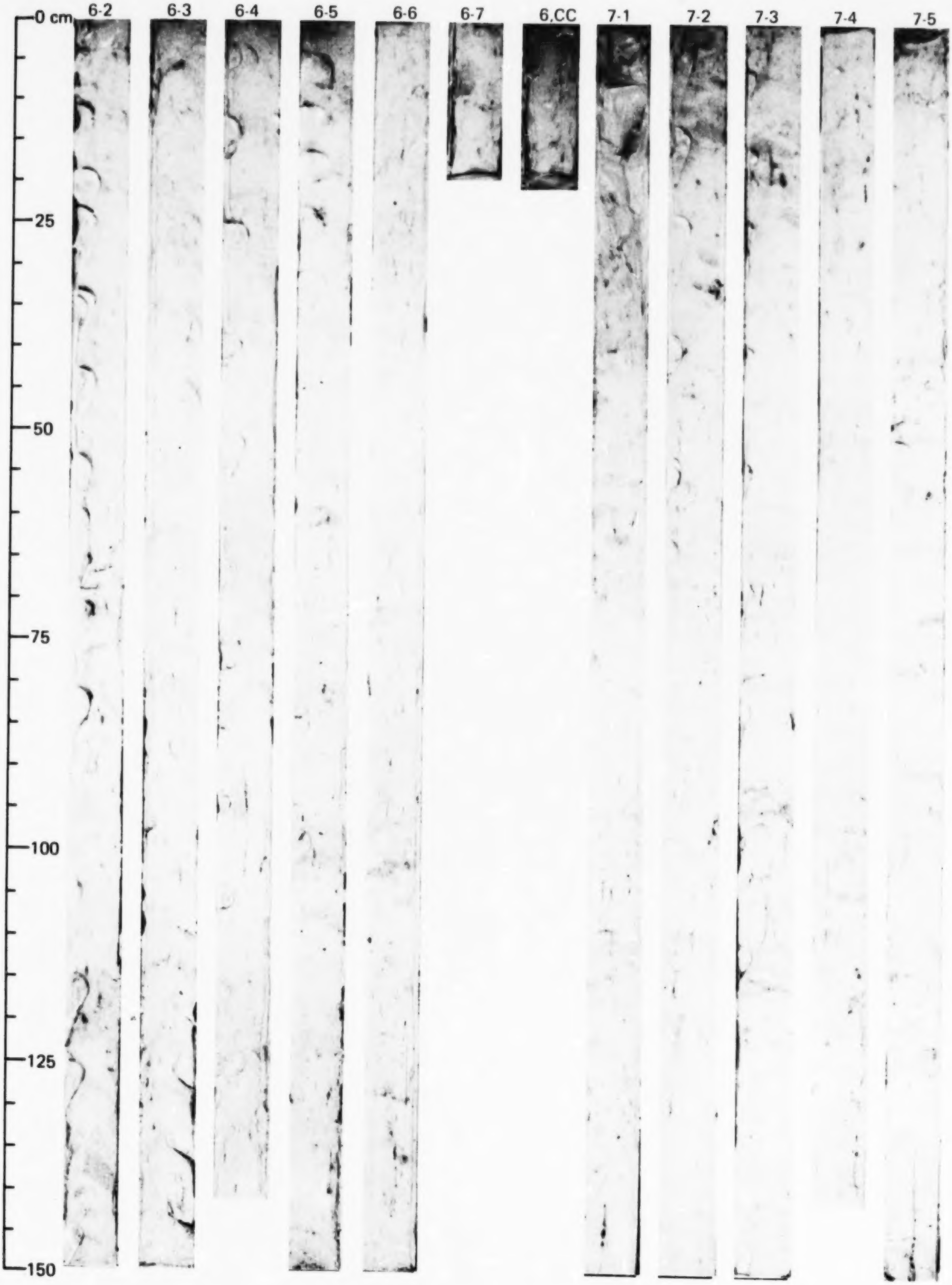
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6,CC
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7-2
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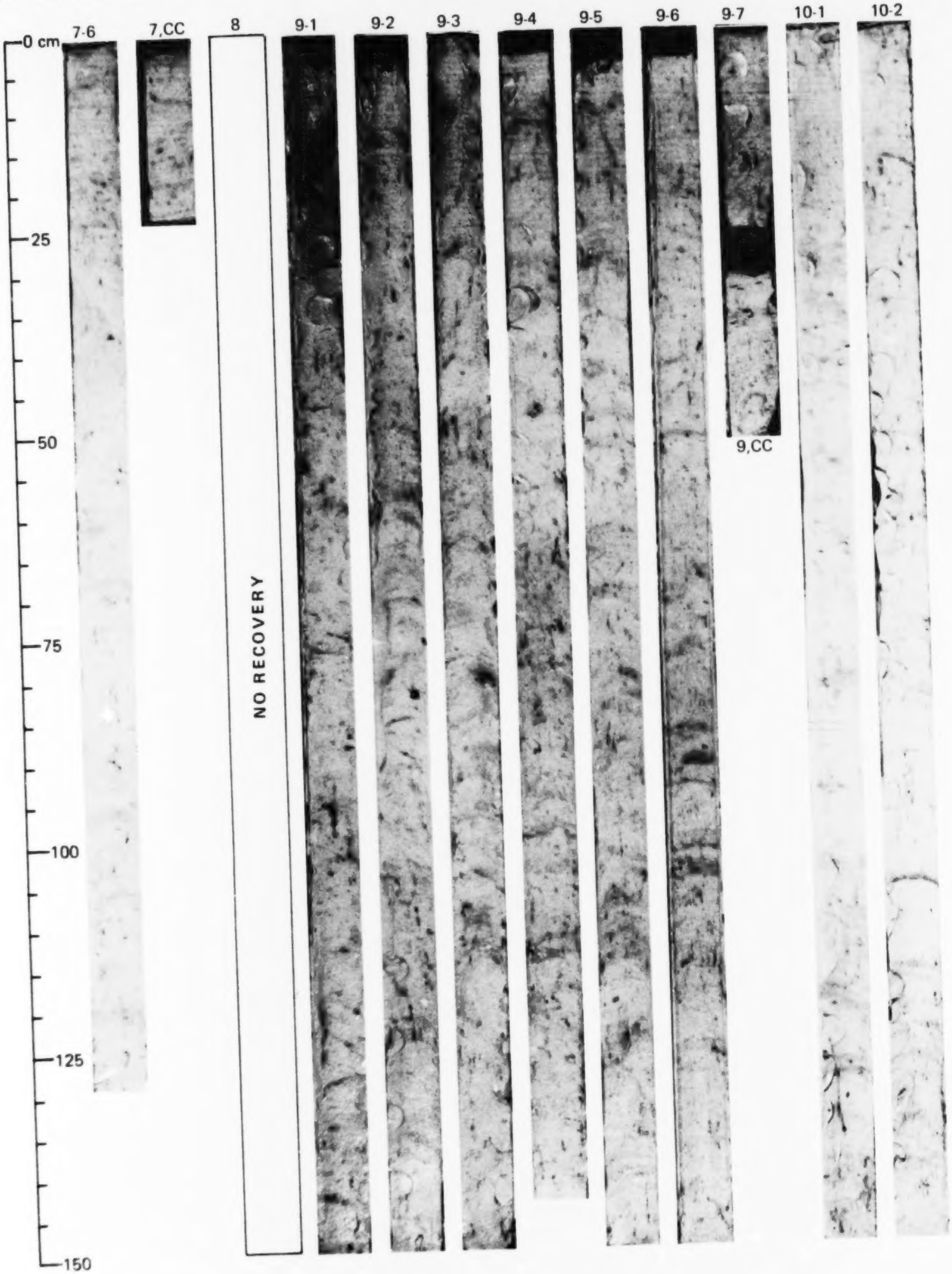
7-4
7-5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7-6
7,CC
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9-2
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9,CC
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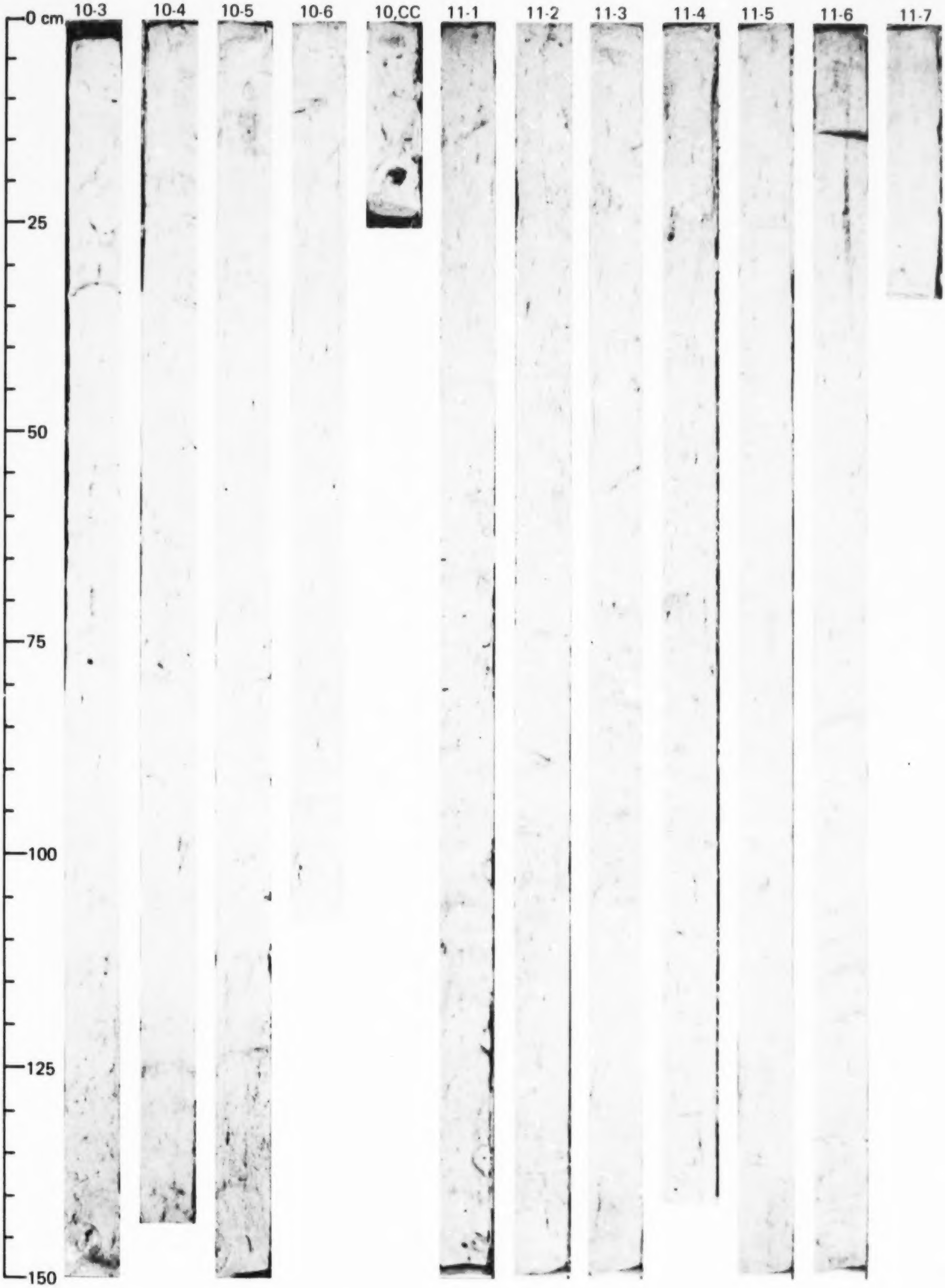
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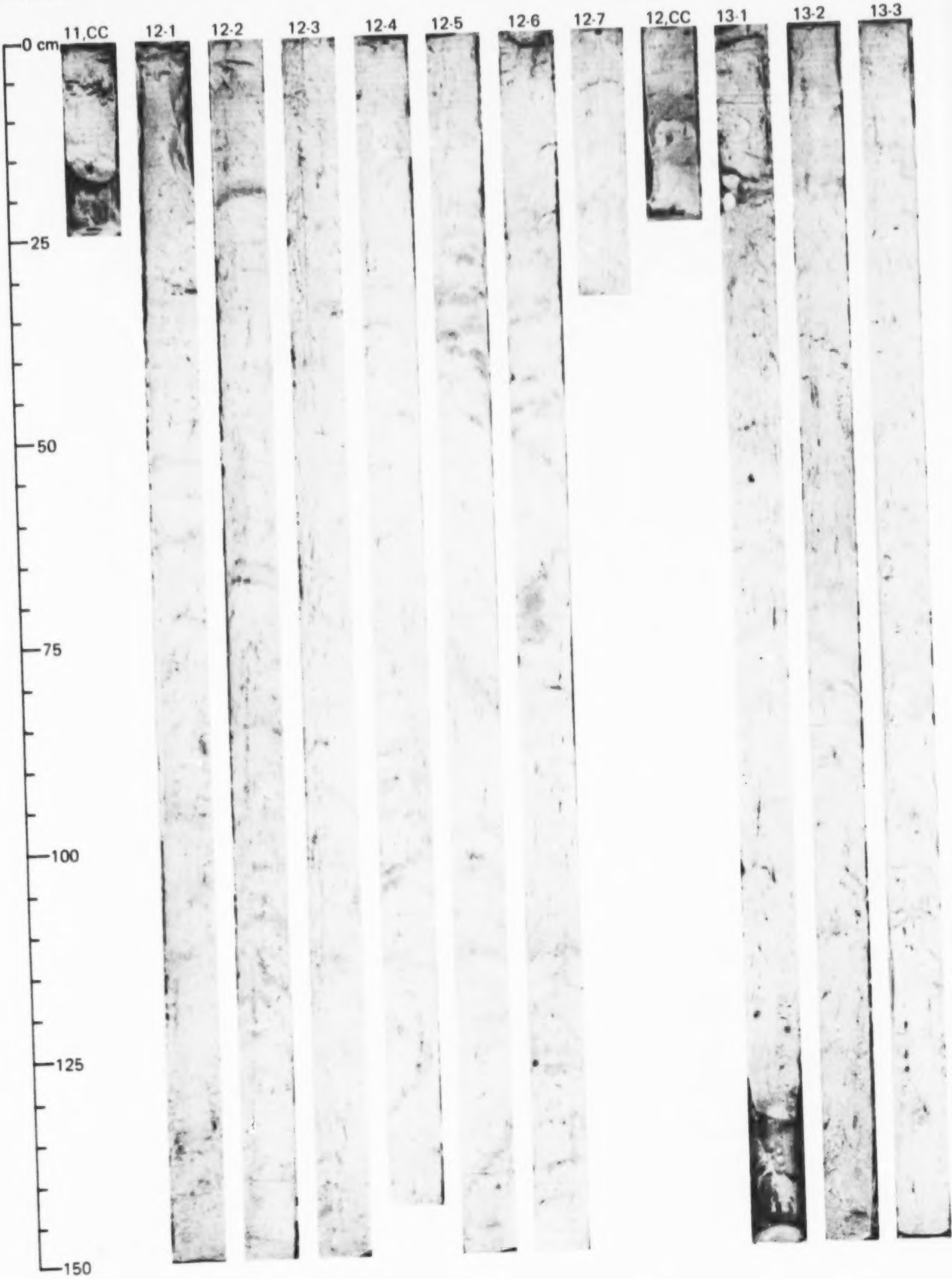
11-7


11,CC
12-1
12-2
12-3
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12-5
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12-7
12,CC
13-1
13-2
13-3
0 cm
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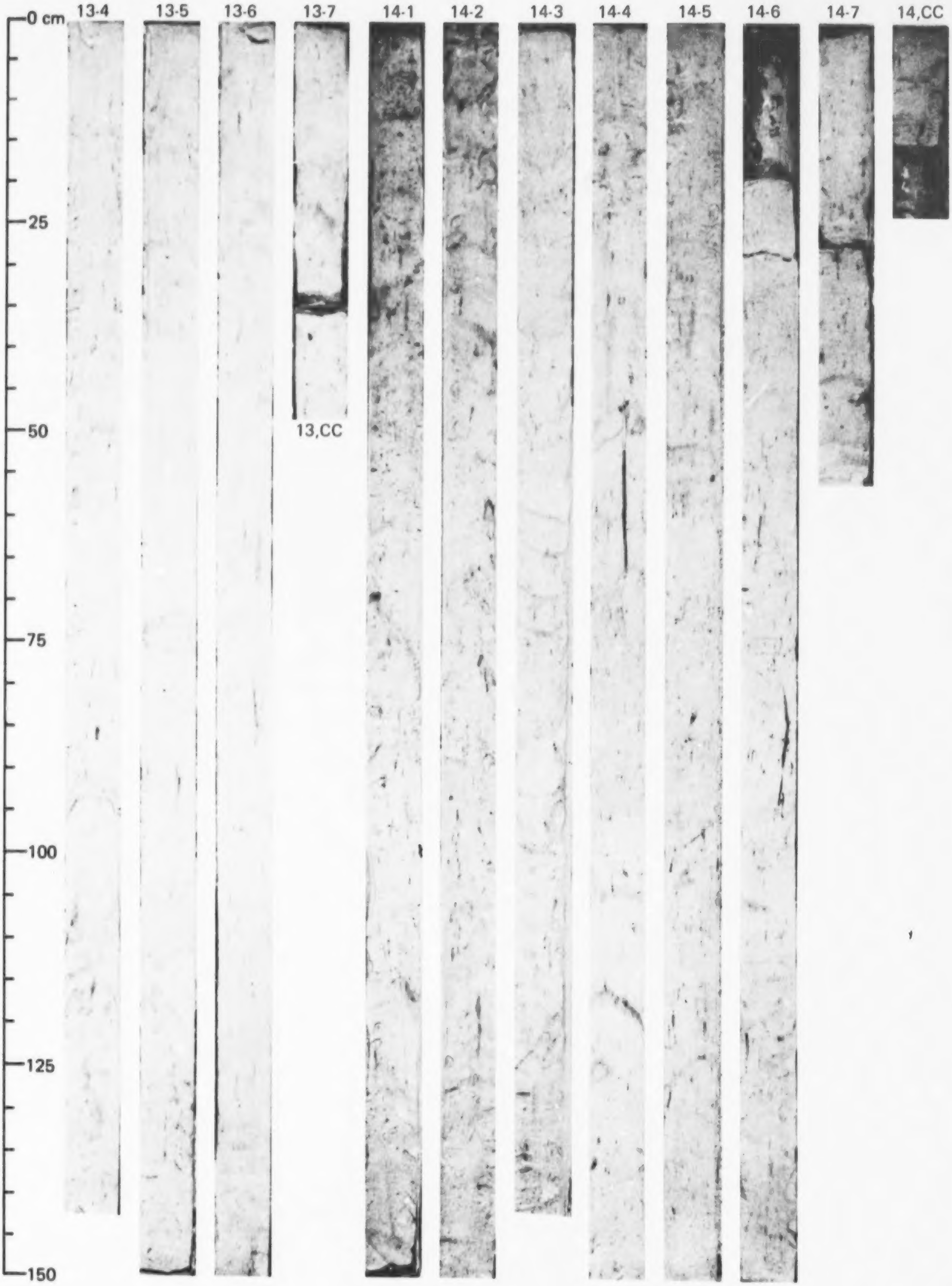
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14-6
14-7
14,CC

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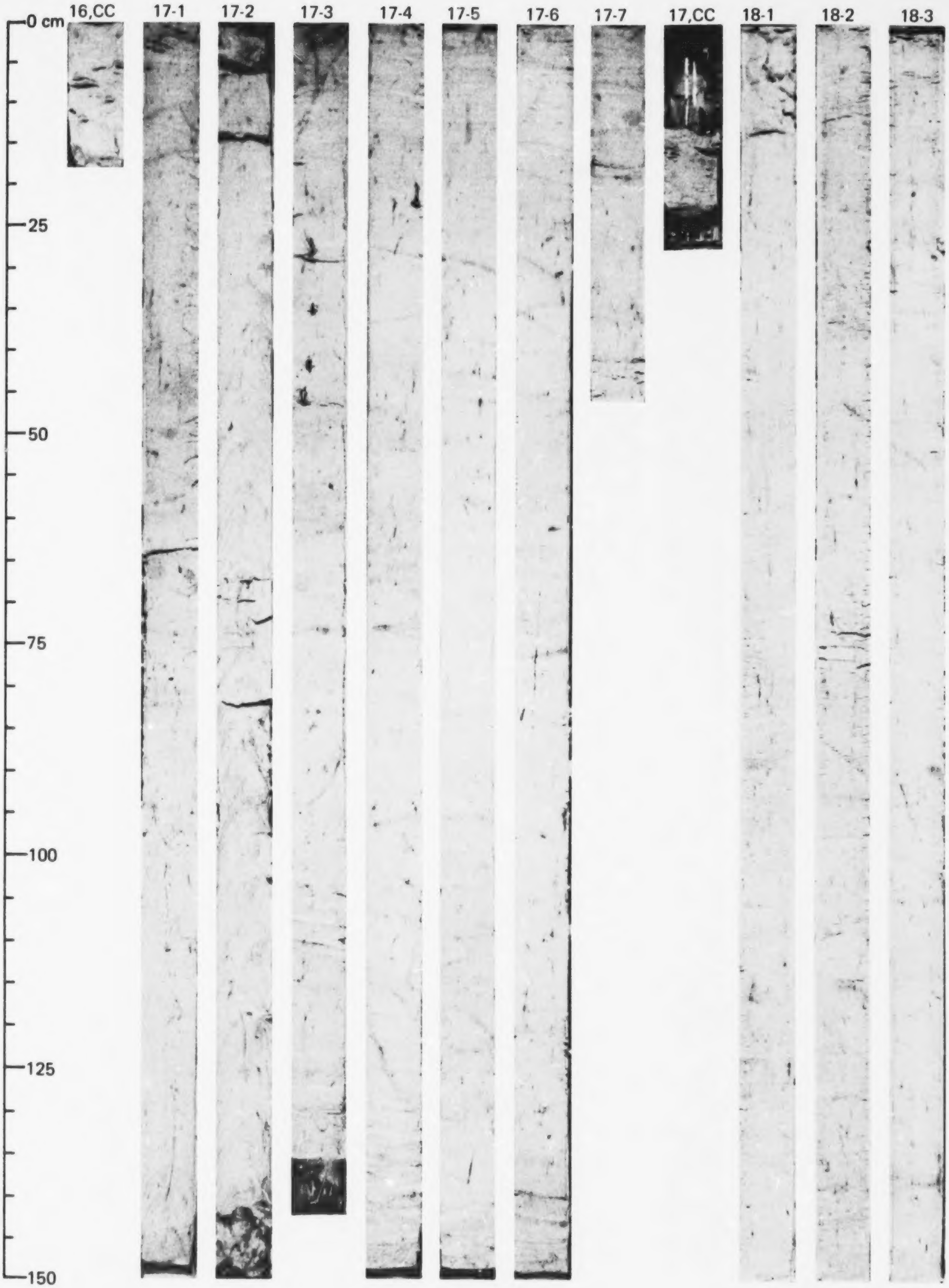
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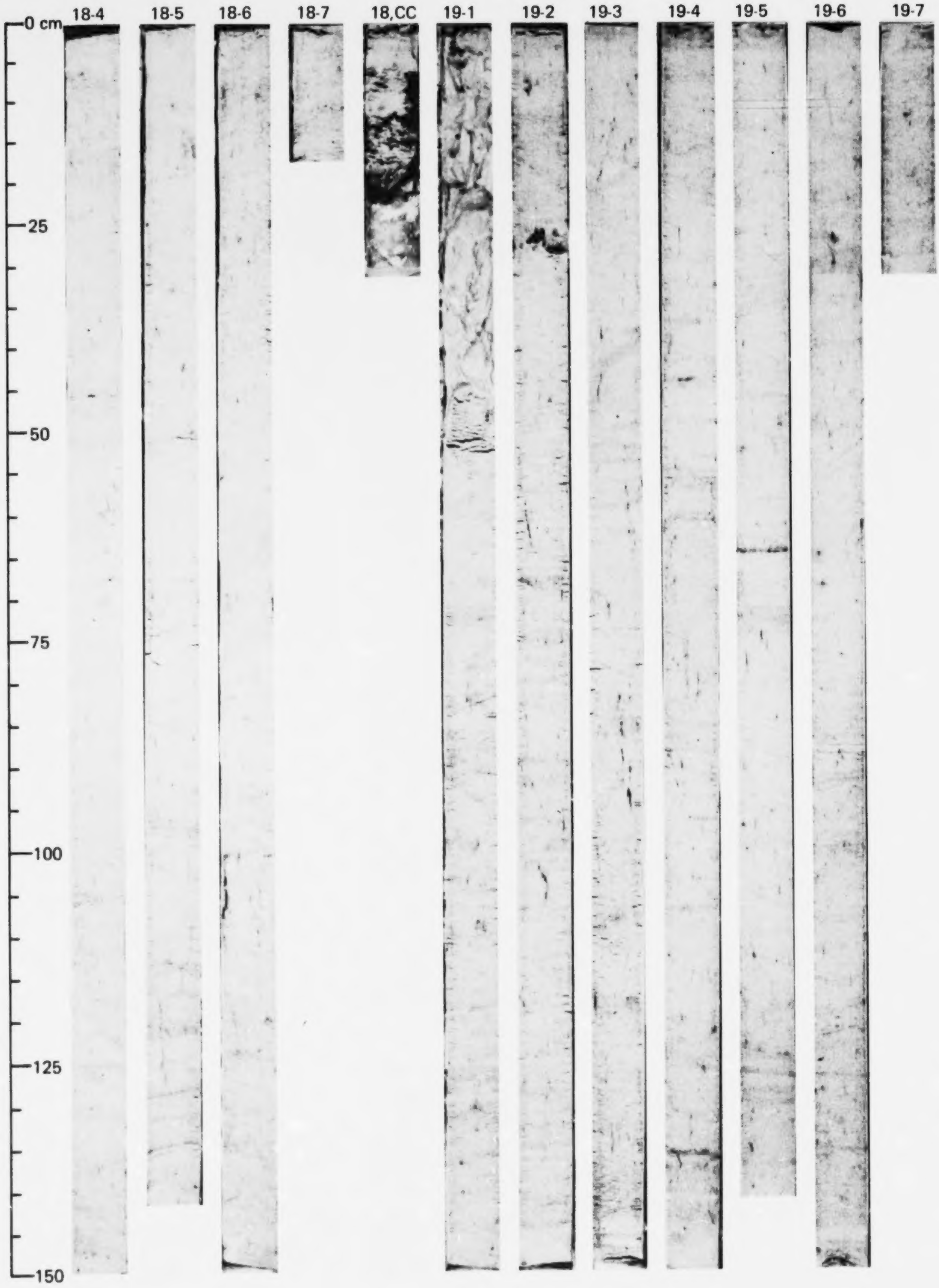
18-4
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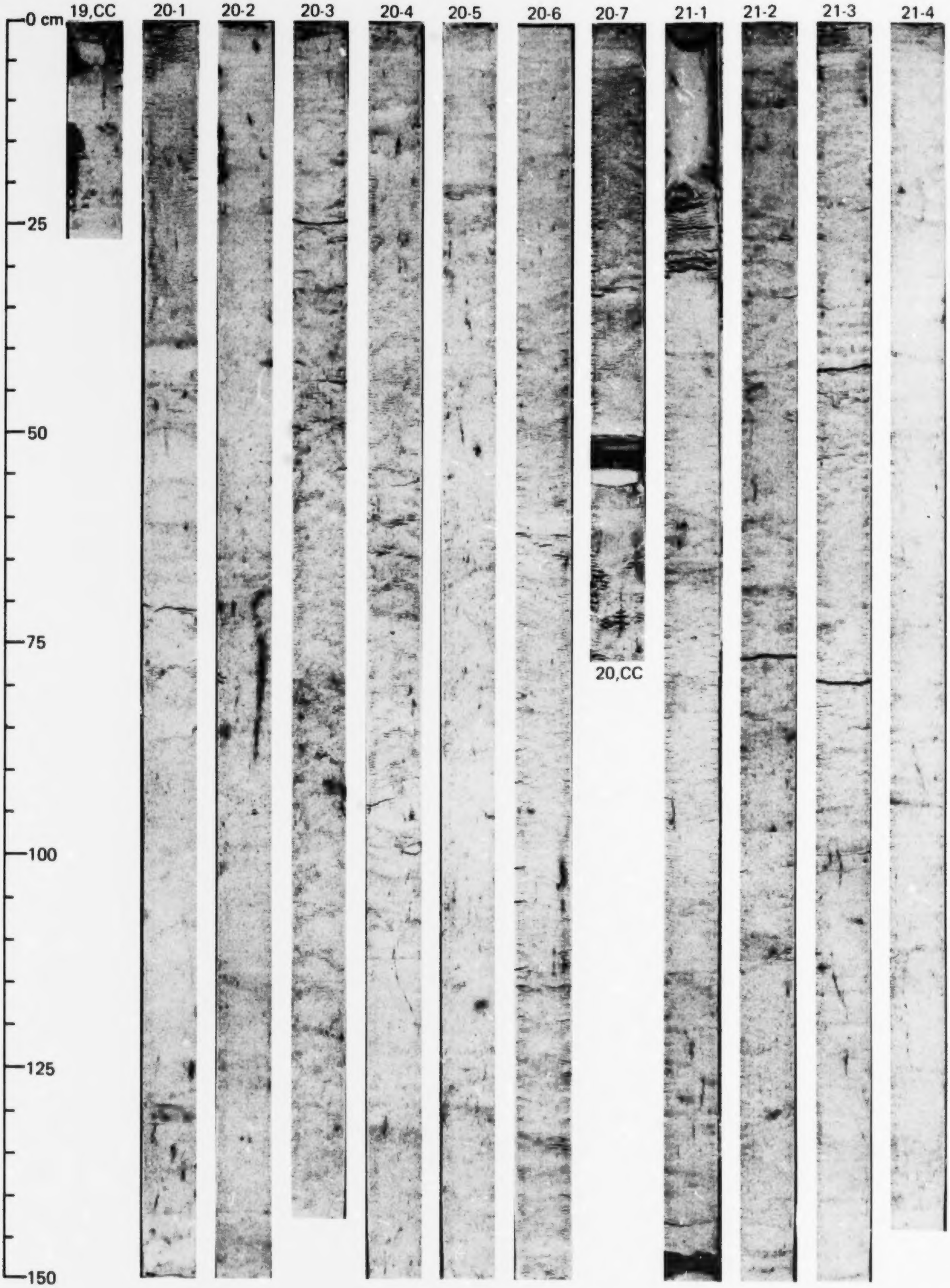
0 cm
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19,CC
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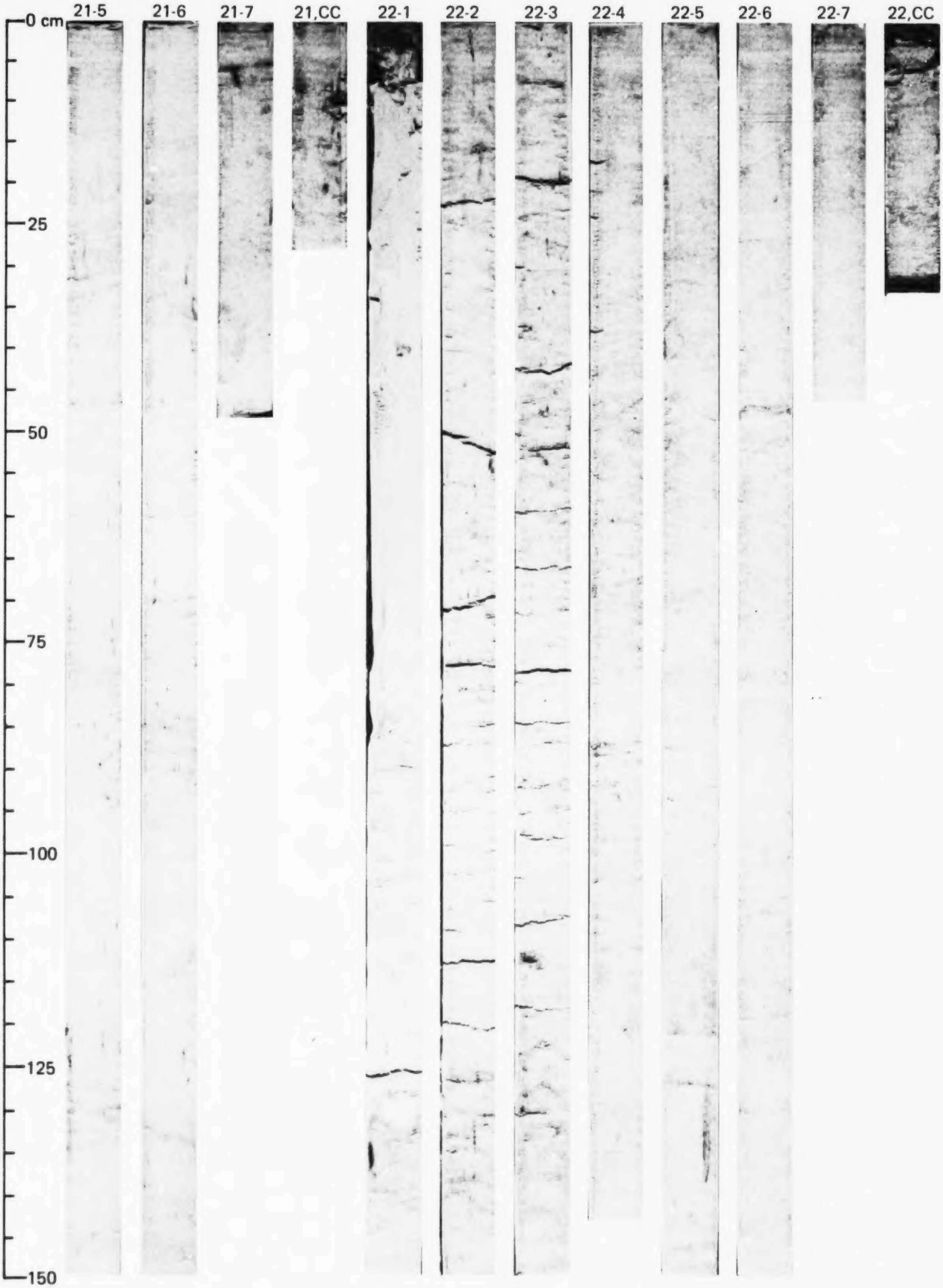
21-5
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21,CC
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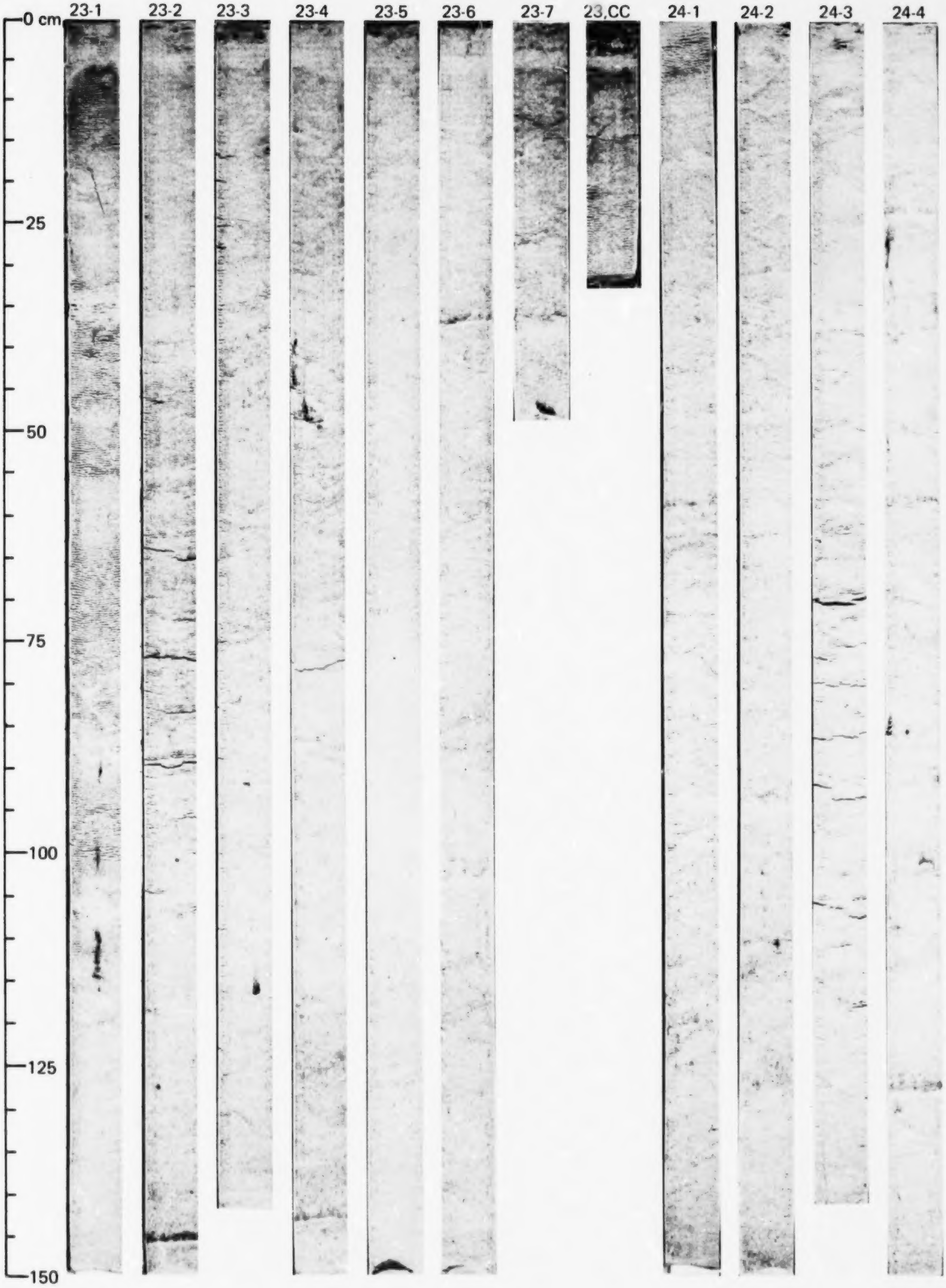
23-1
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23,CC
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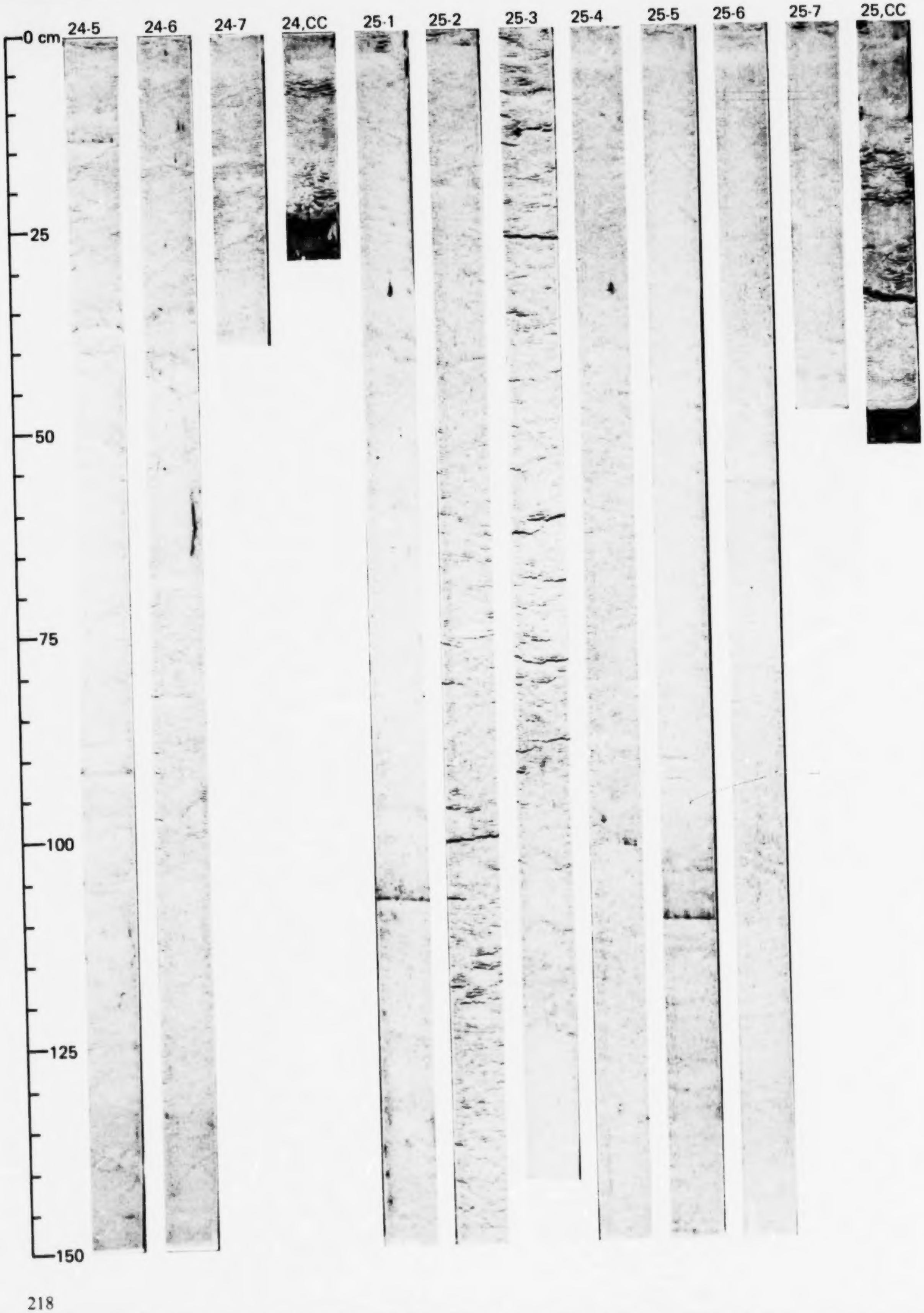
24-5
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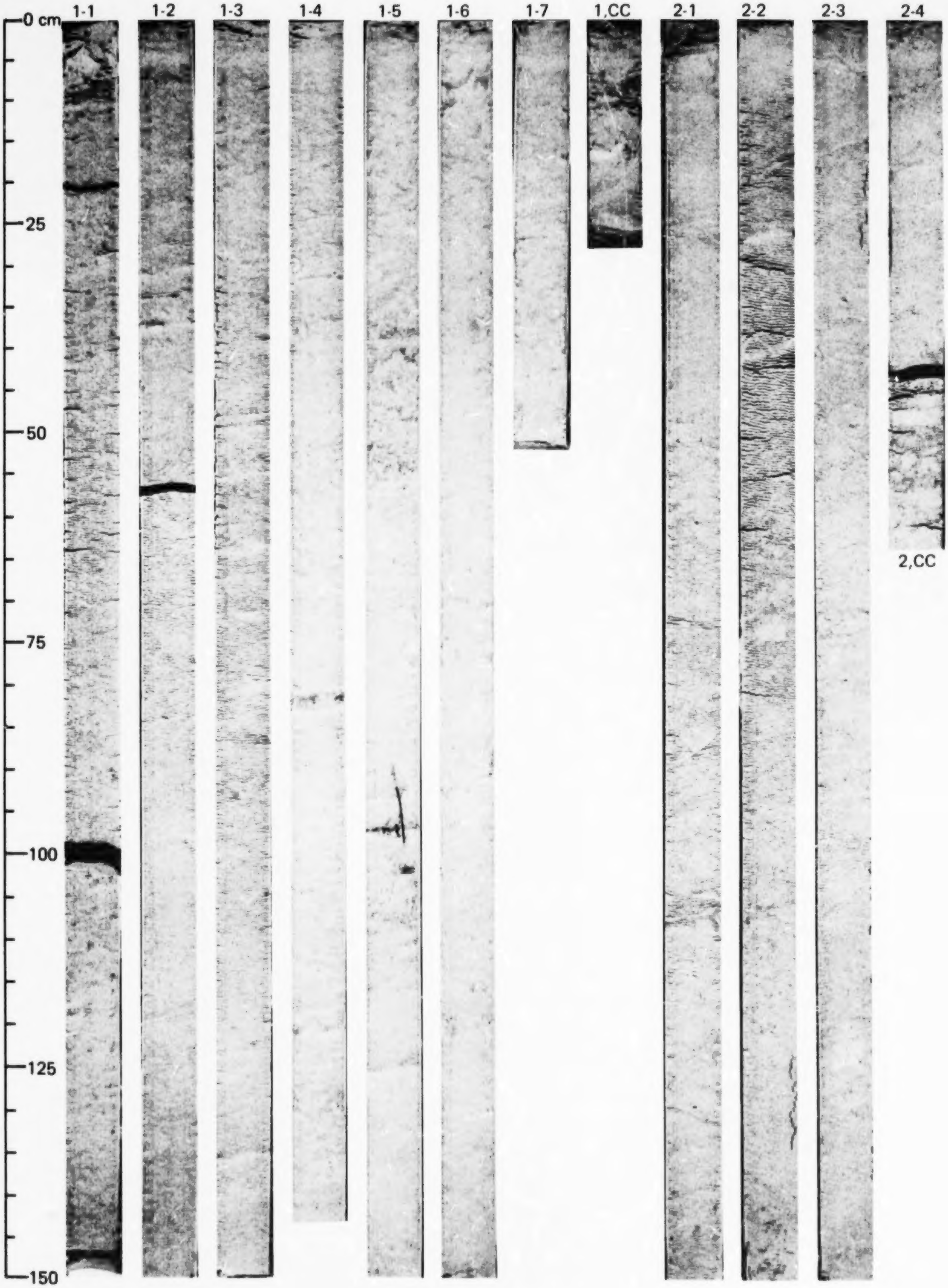
1-1
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2-1
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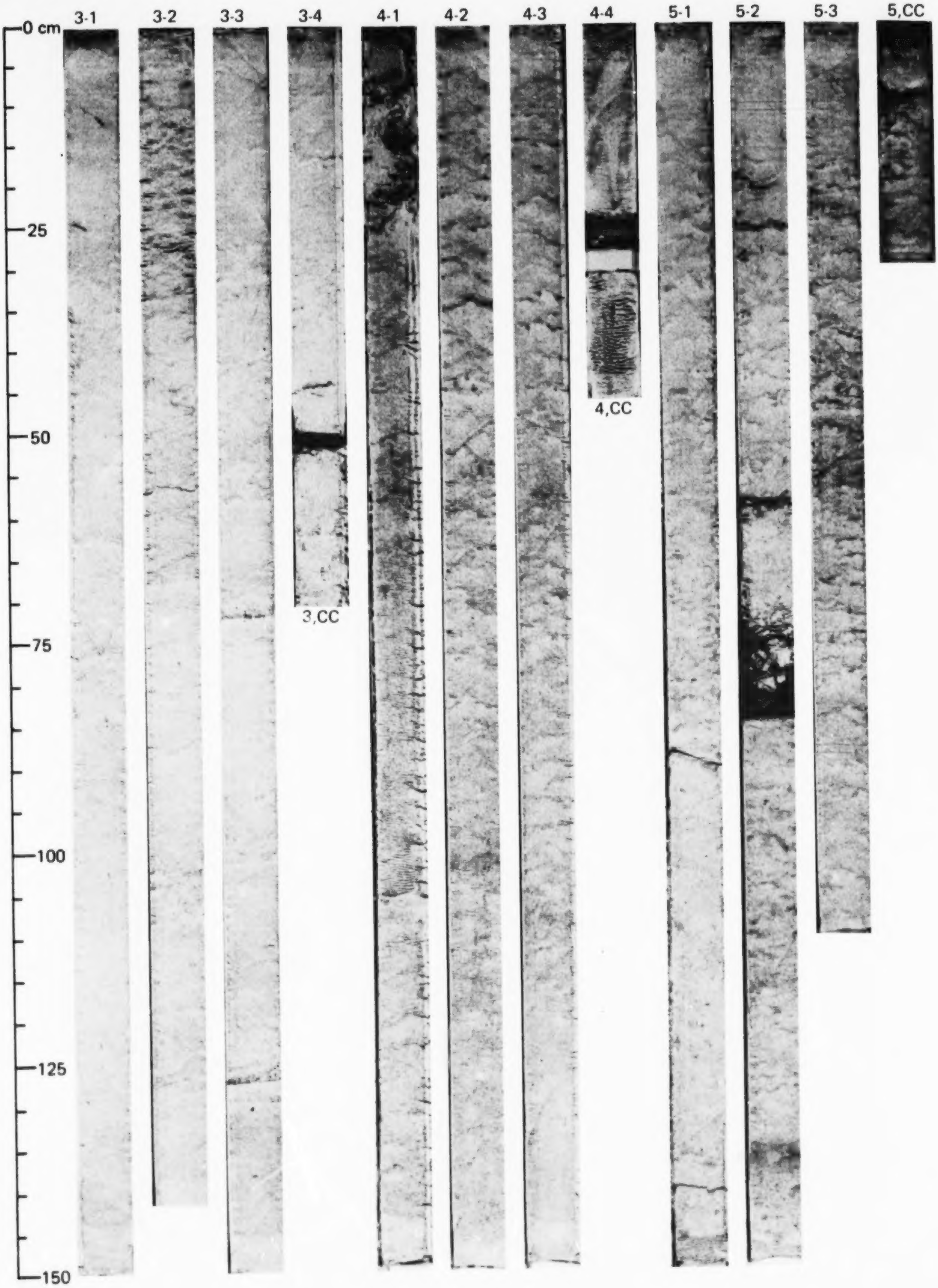
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4-2
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5,CC
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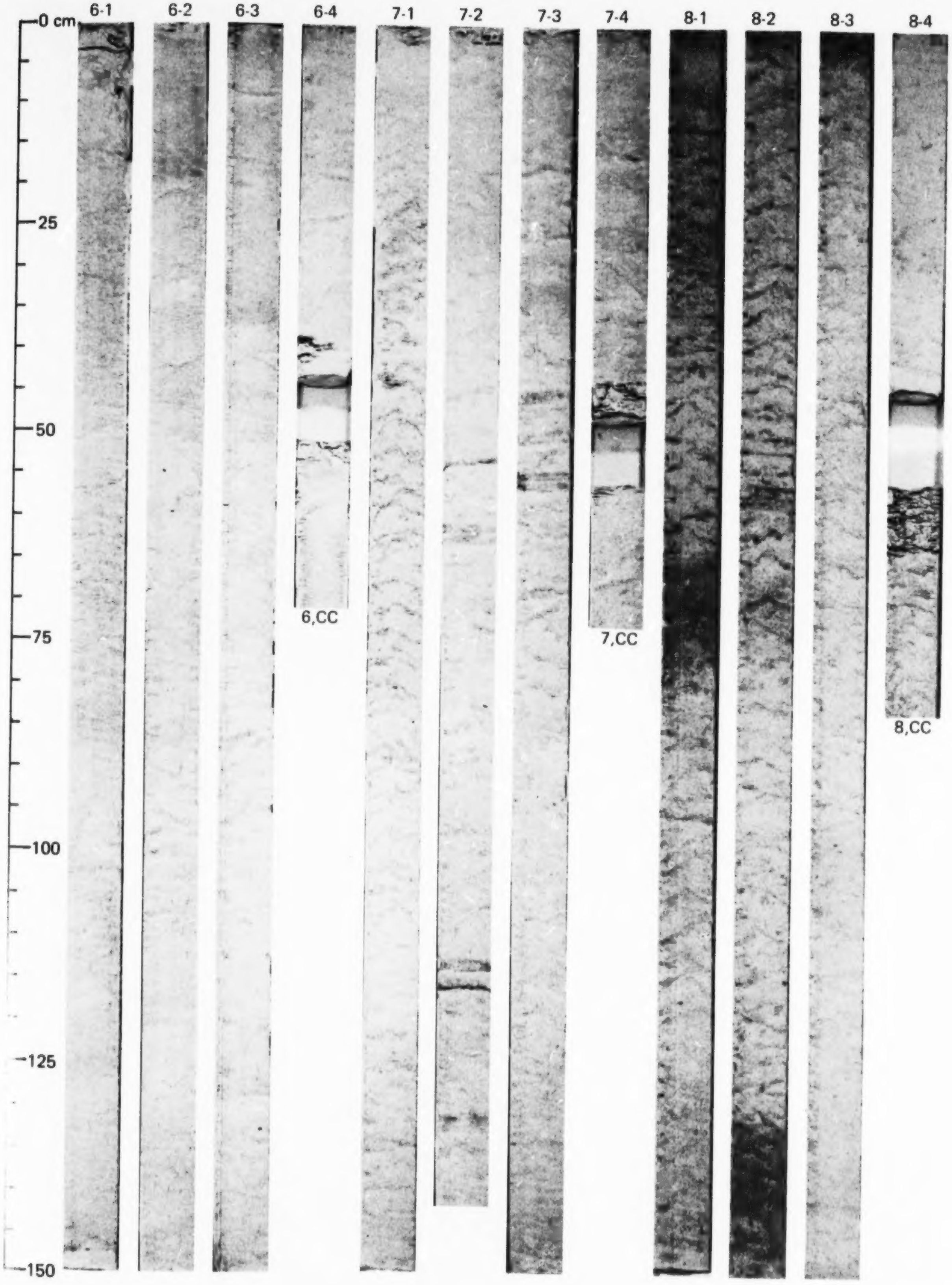
3,CC
4,CC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7,CC
8-1
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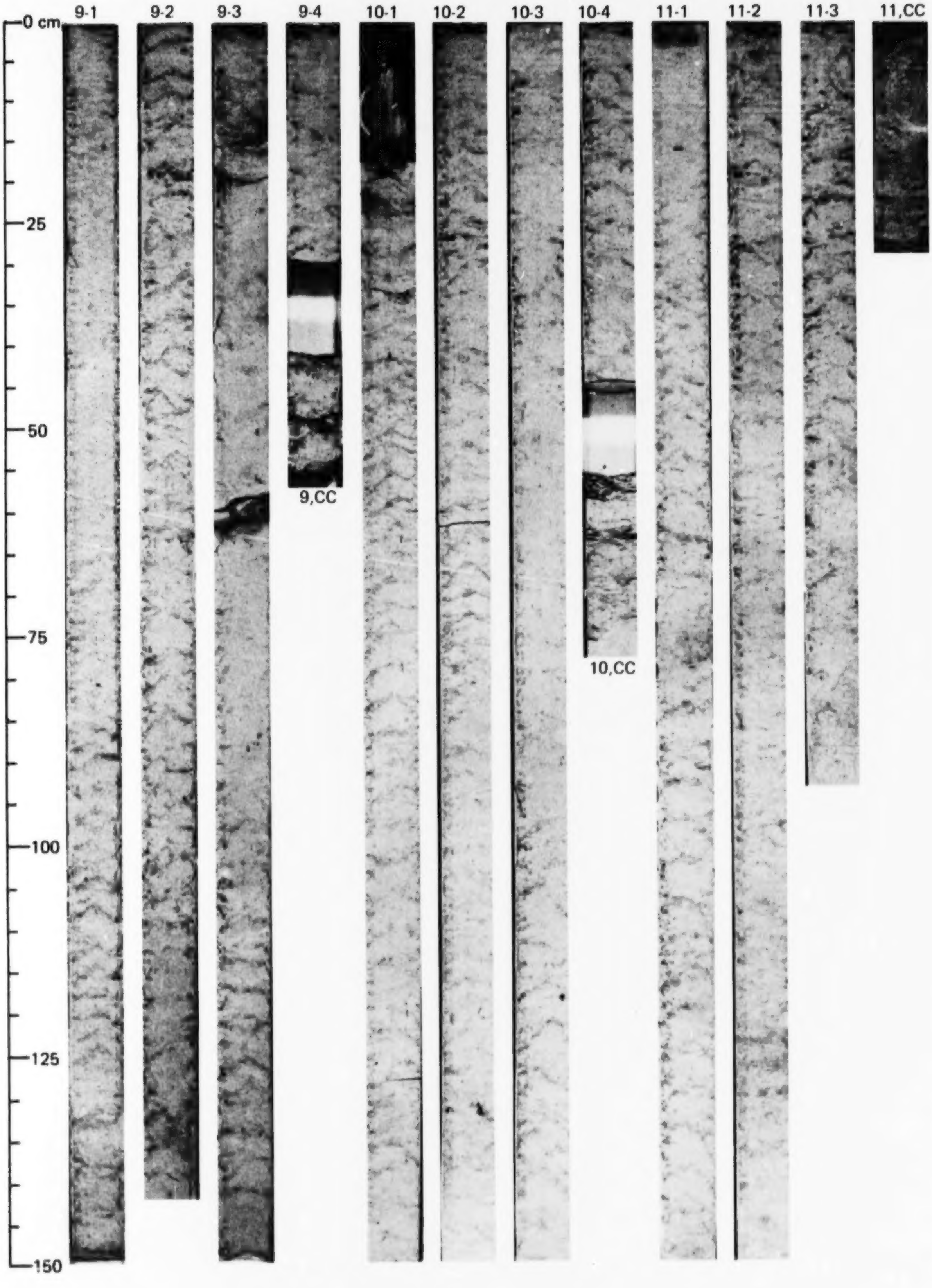
8,CC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9,CC
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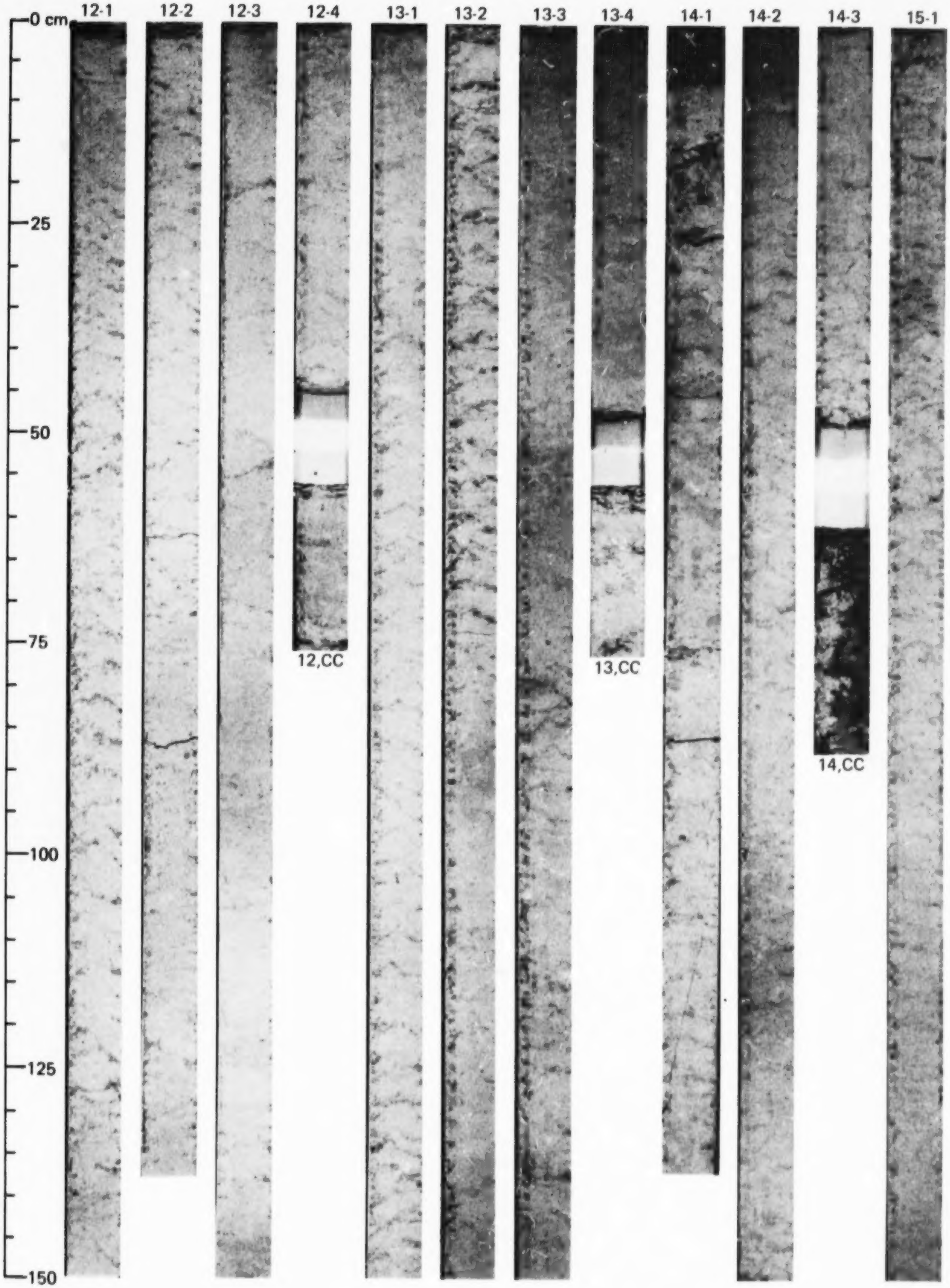

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15-1
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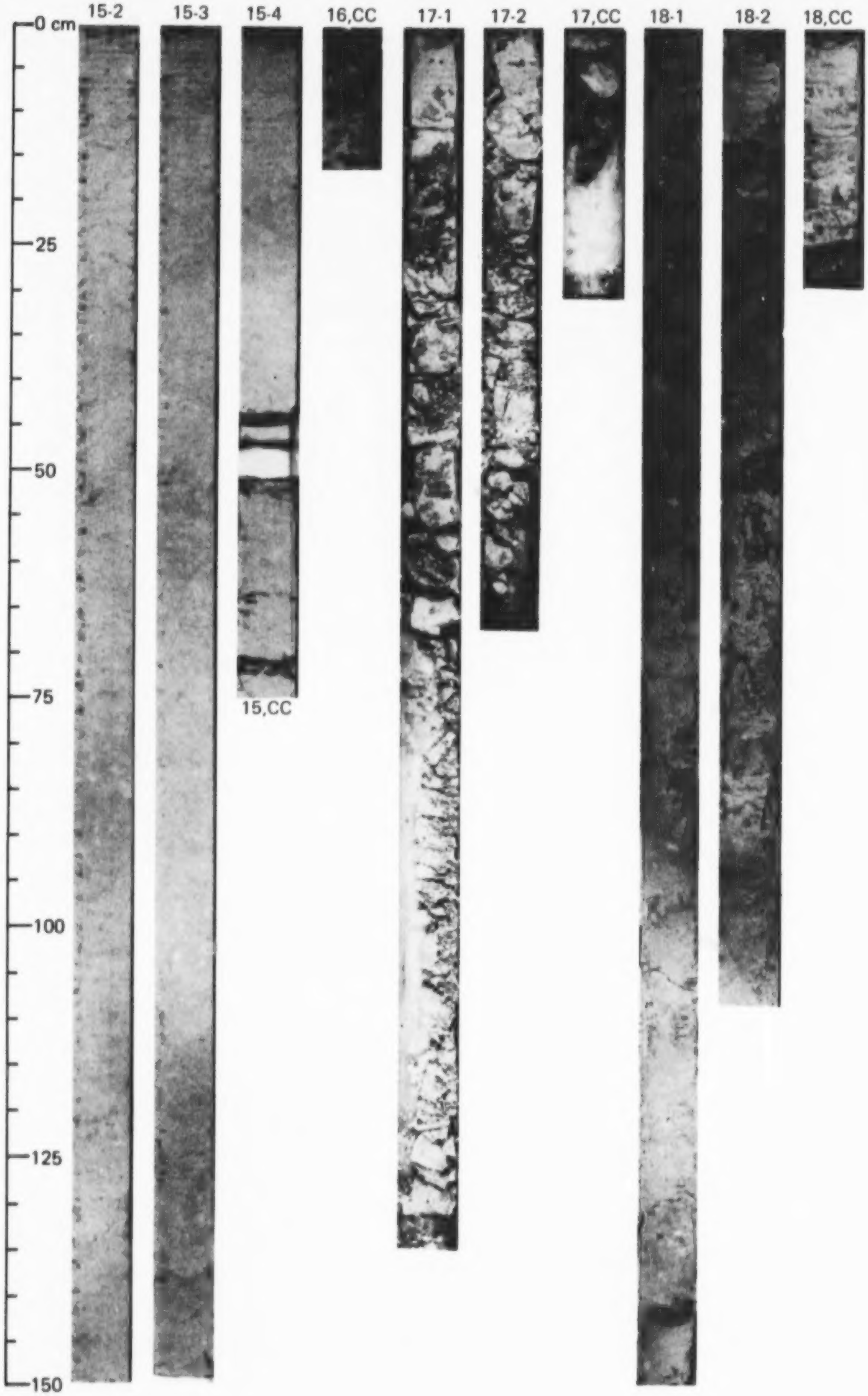
13,CC
14,CC


15-2
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17,CC
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18,CC
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0 cm
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1-6
1,CC
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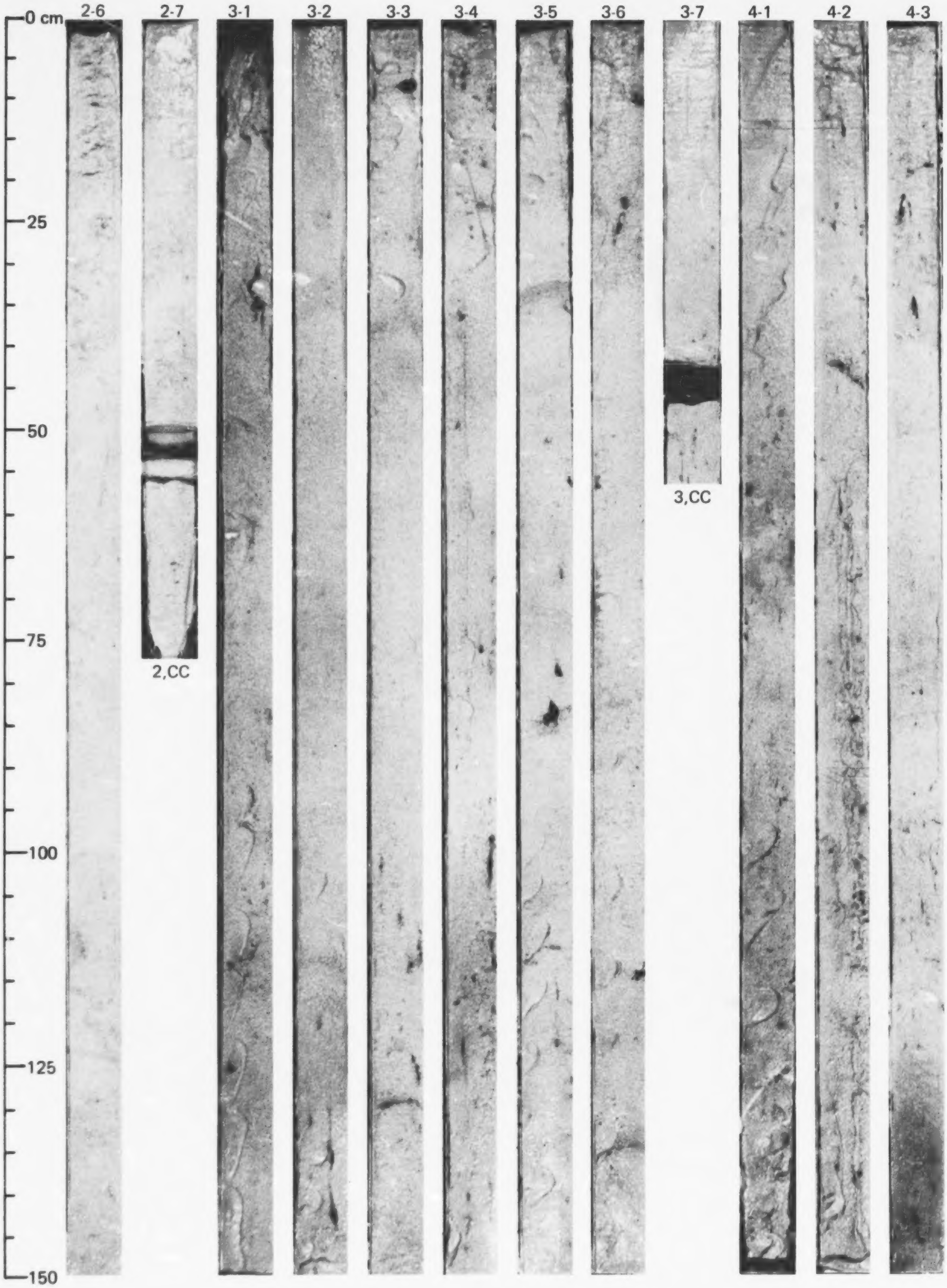
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4-2
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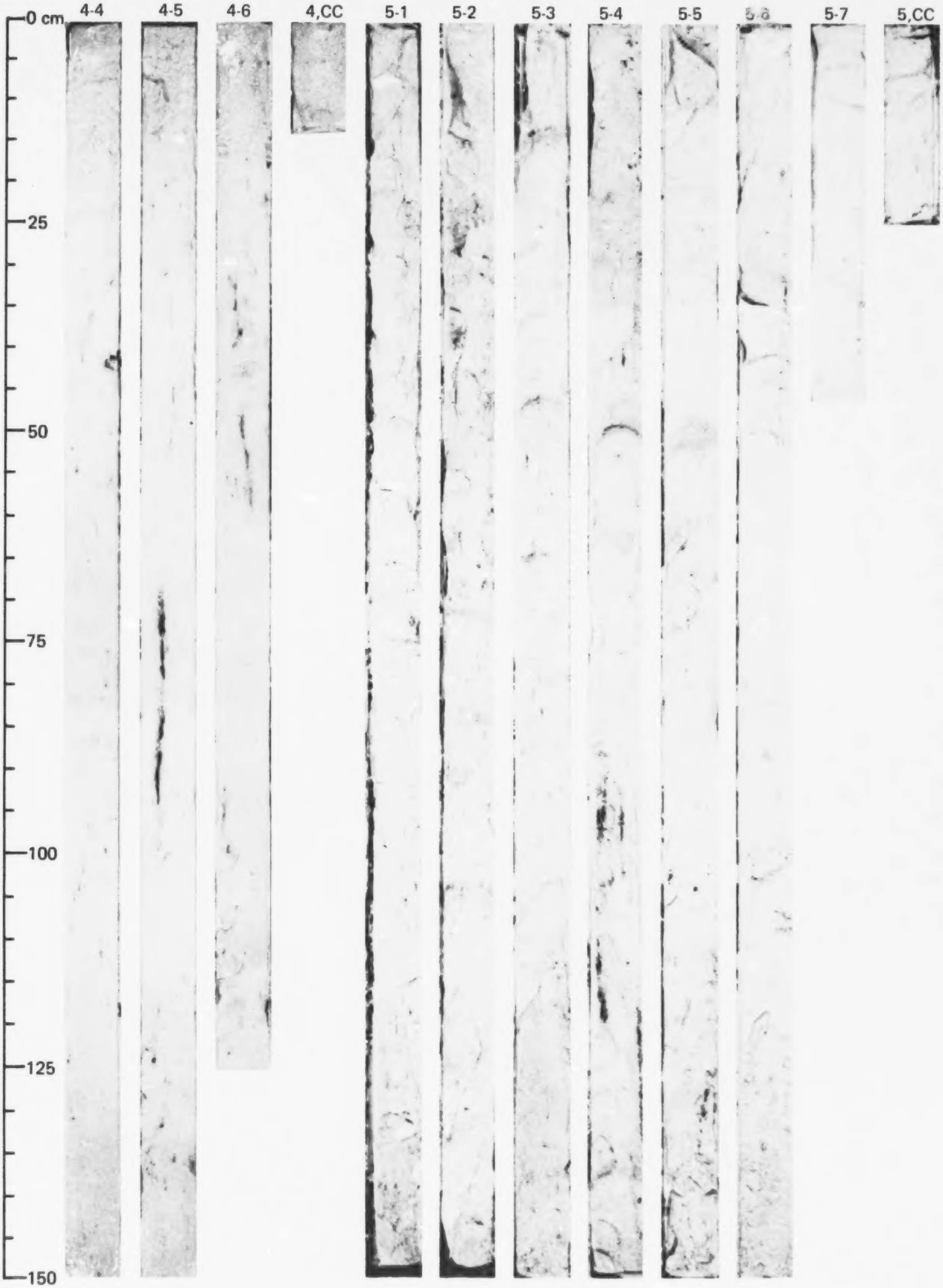
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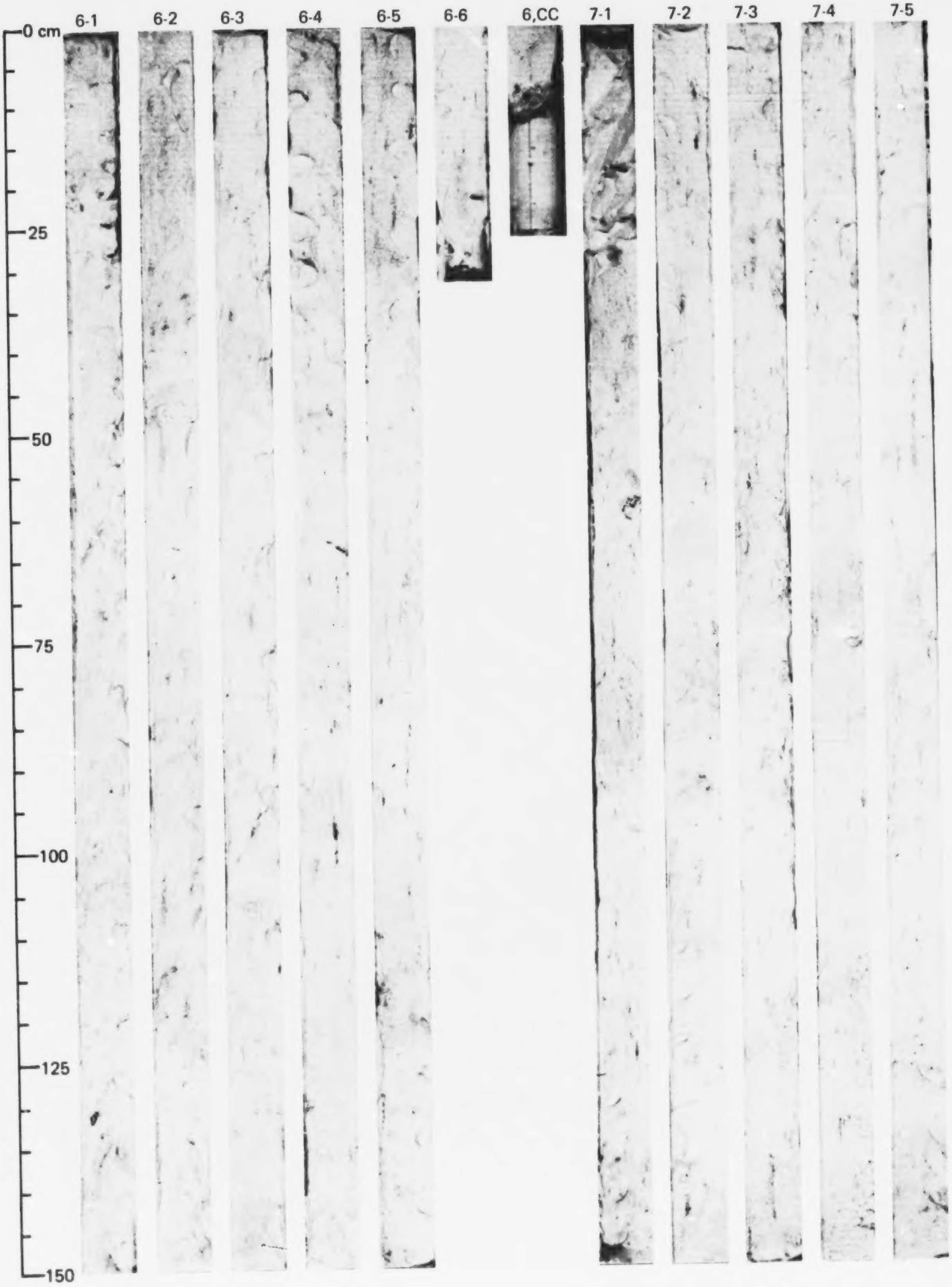
5,CC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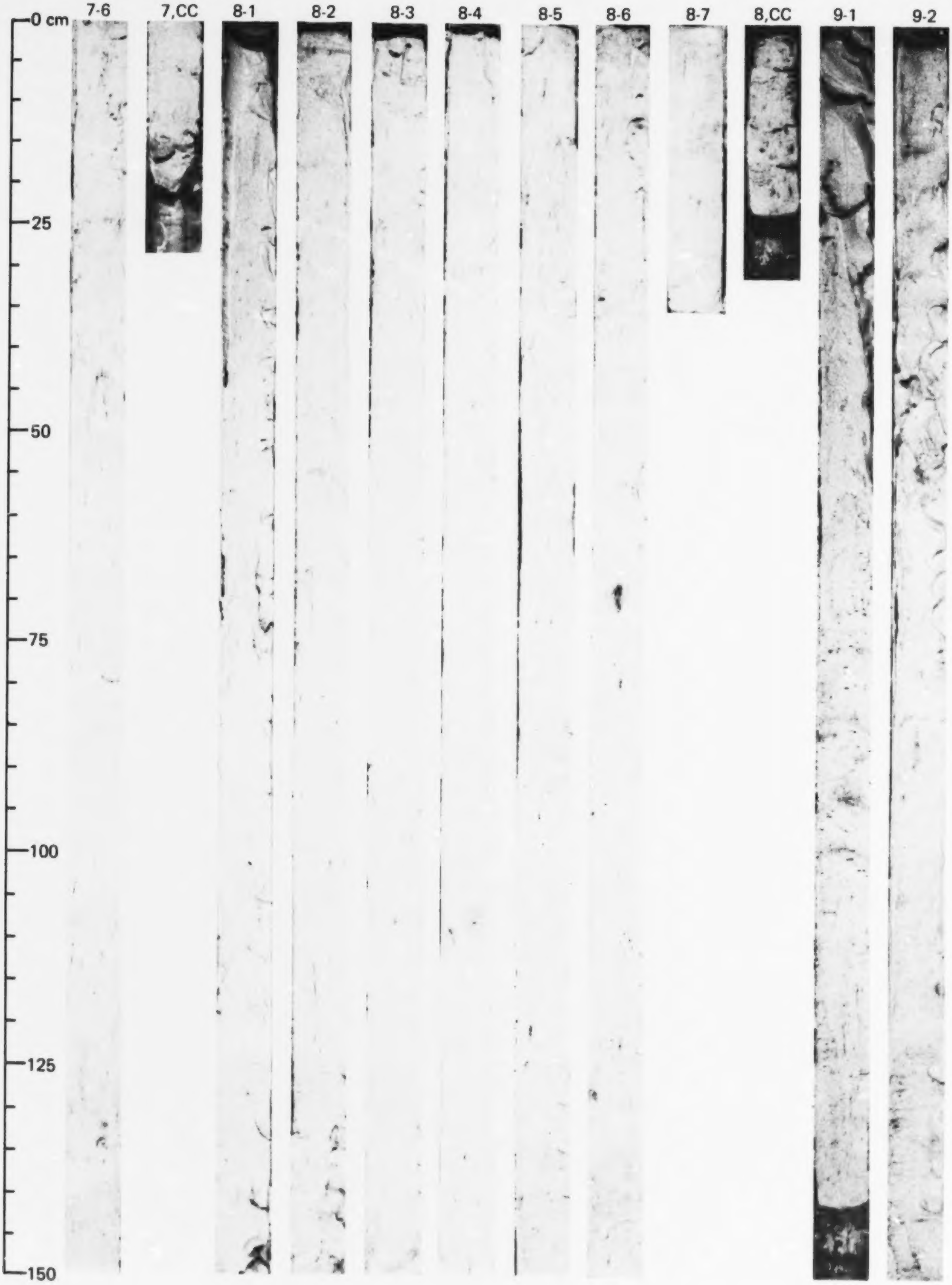
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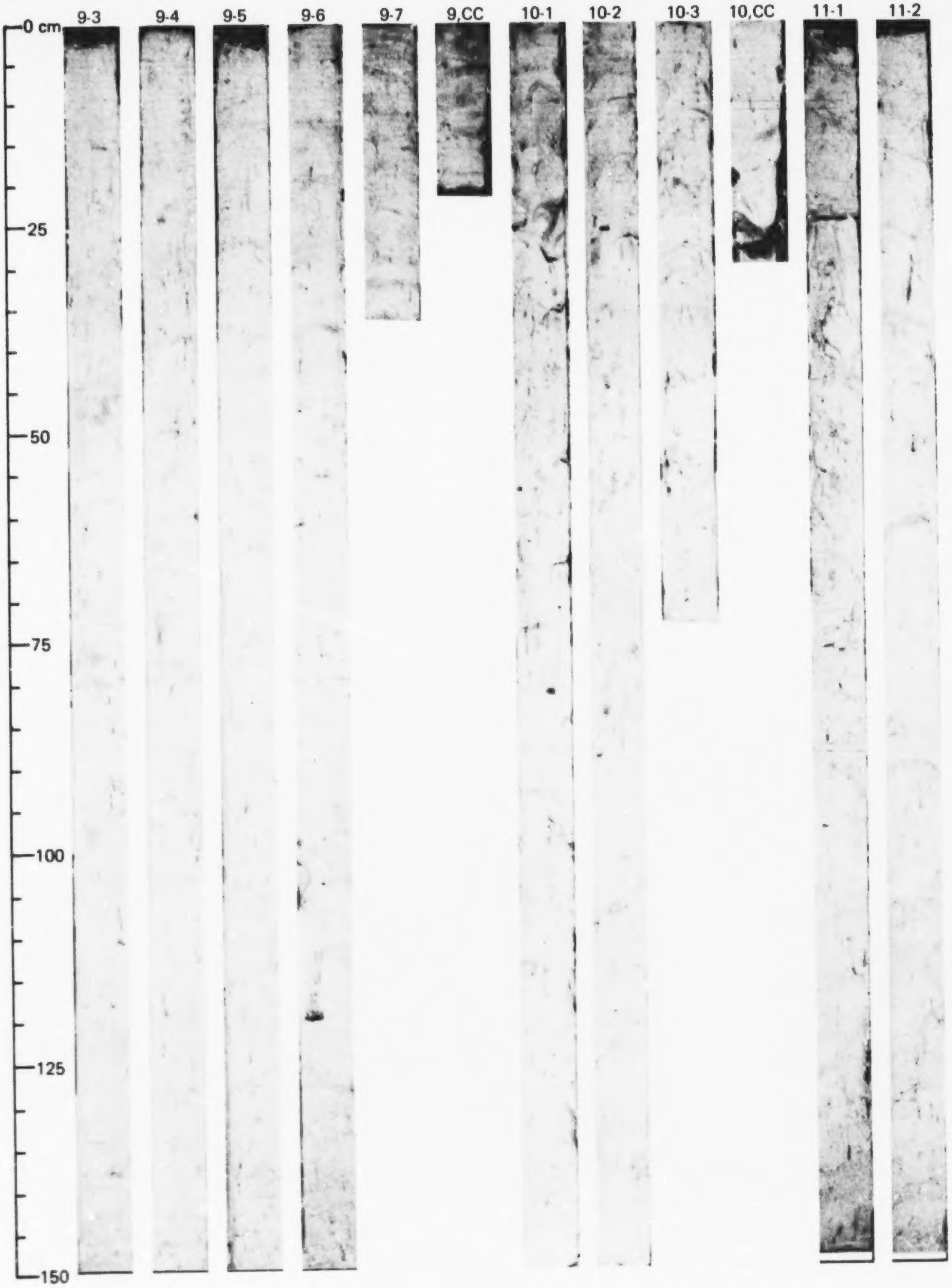
9-1
9-2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0 cm
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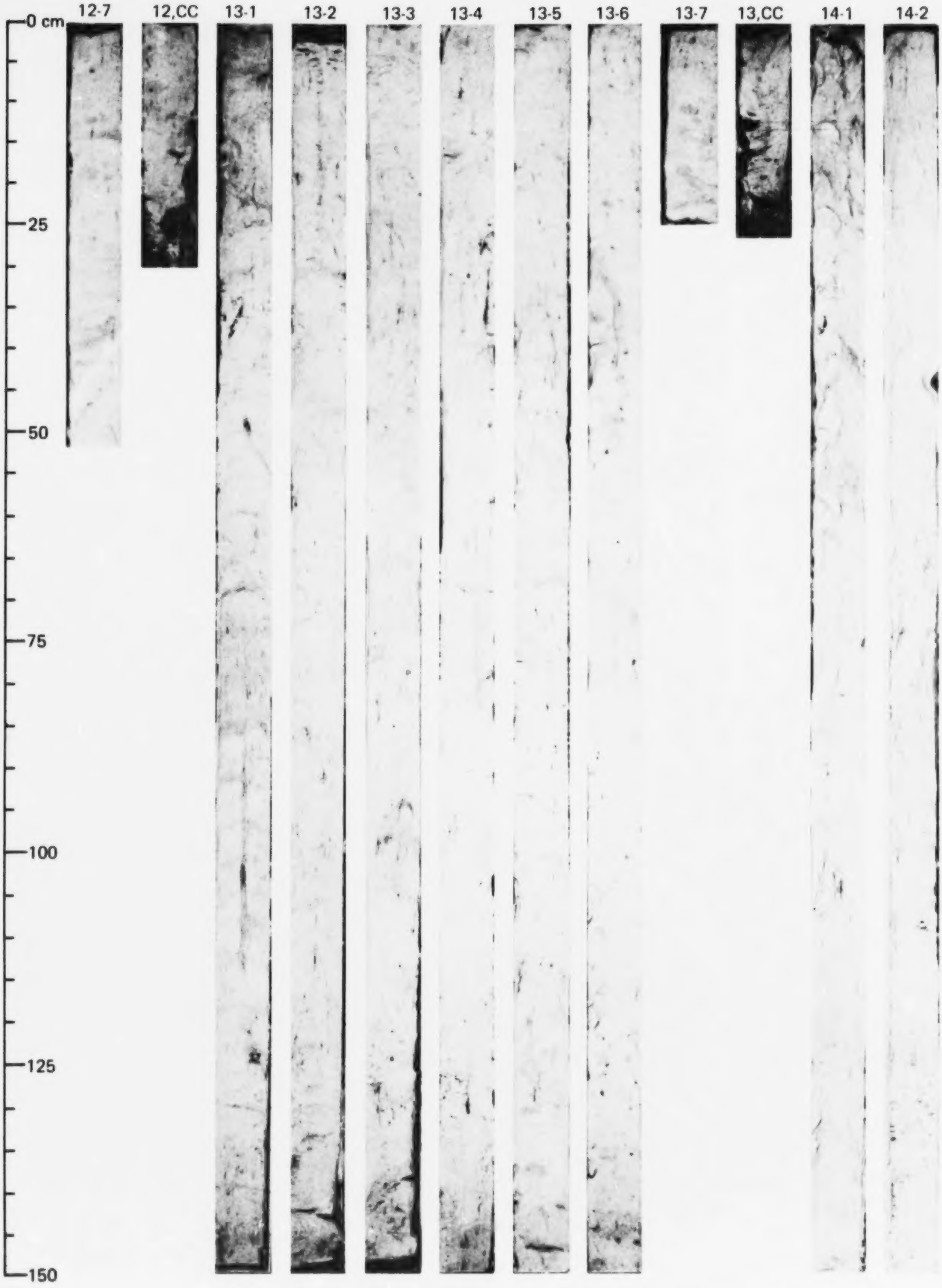
12-7
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13-6
13-7
13,CC
14-1
14-2
0 cm
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14-3
14-4
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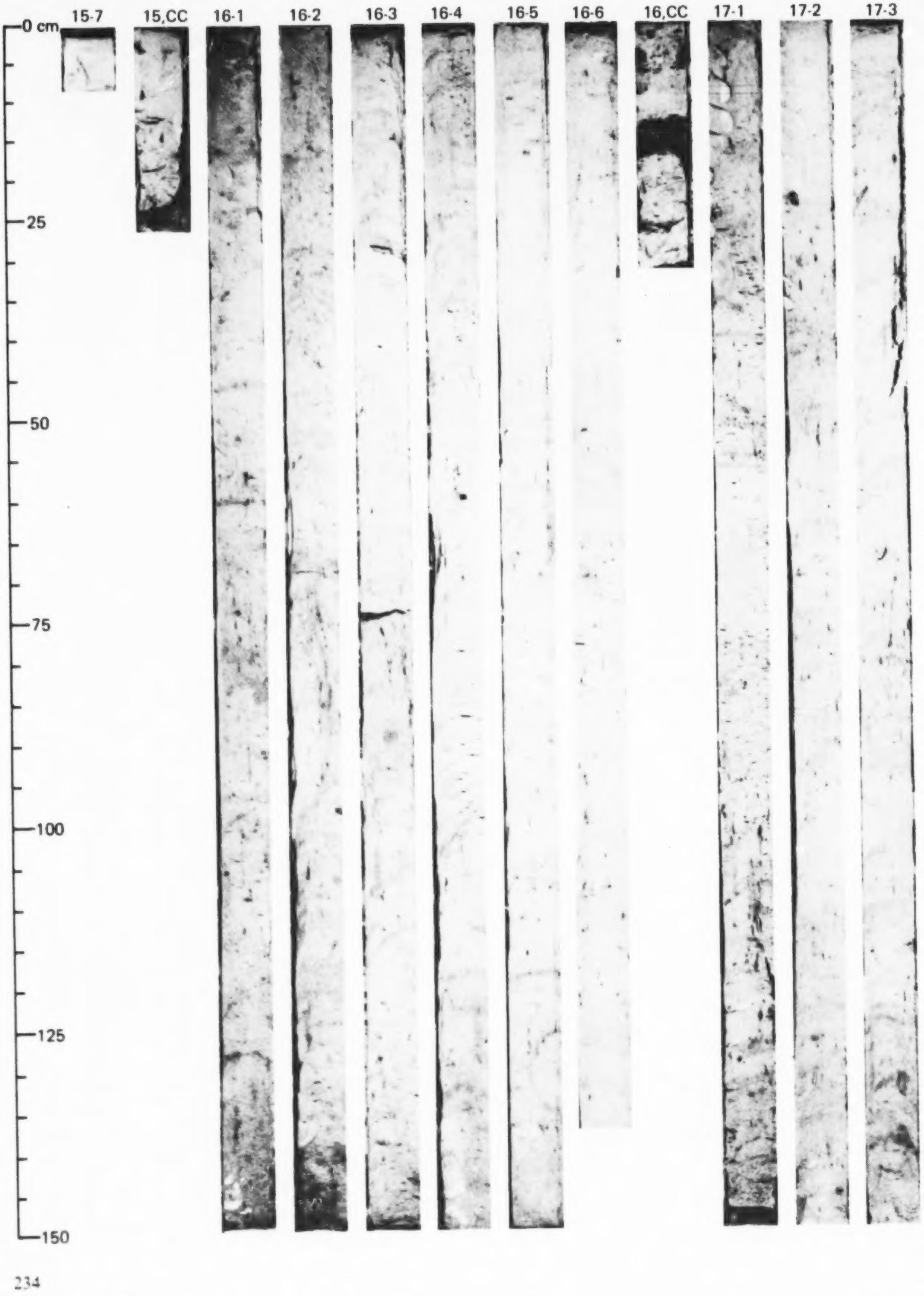
15-7
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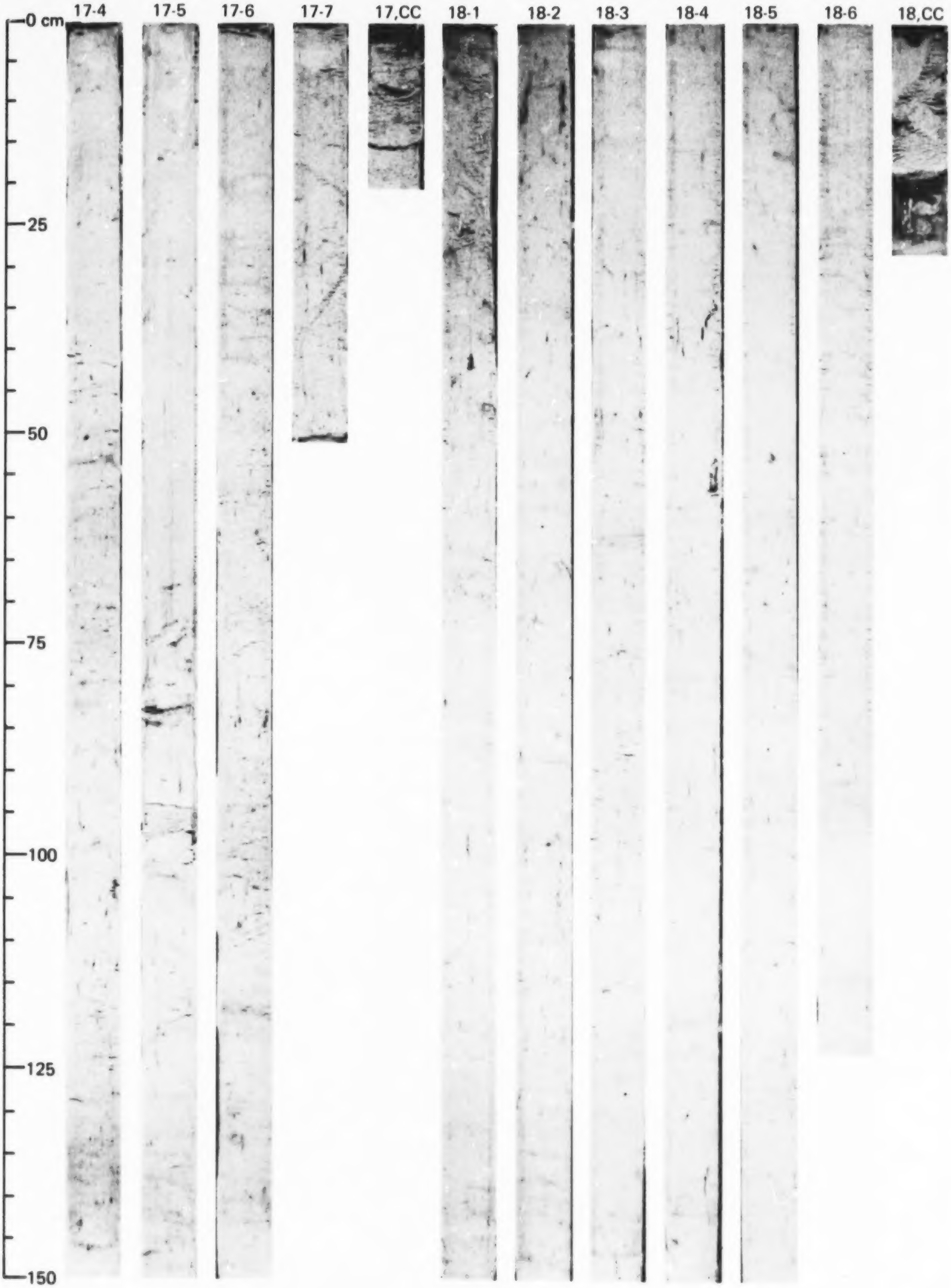
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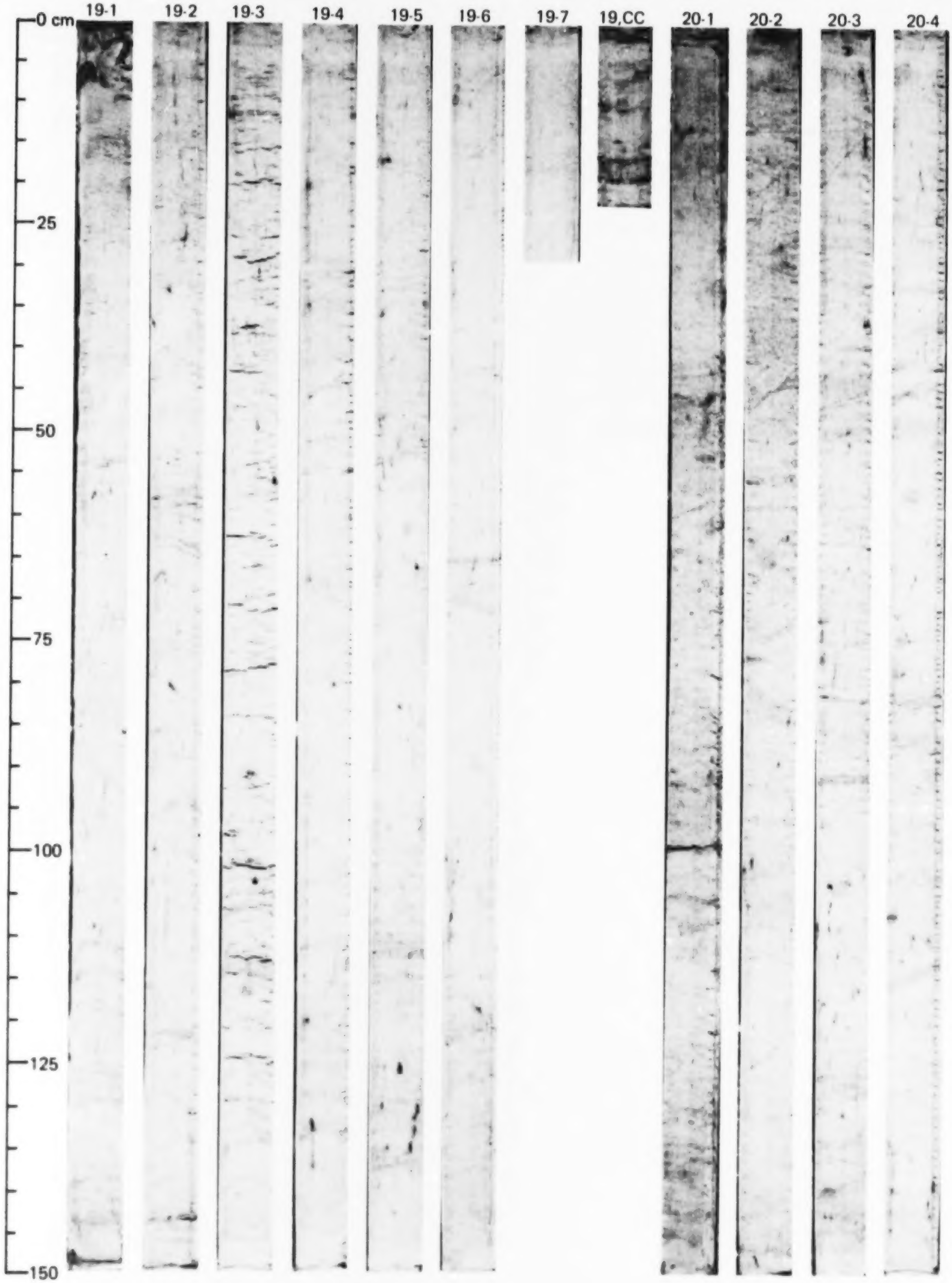
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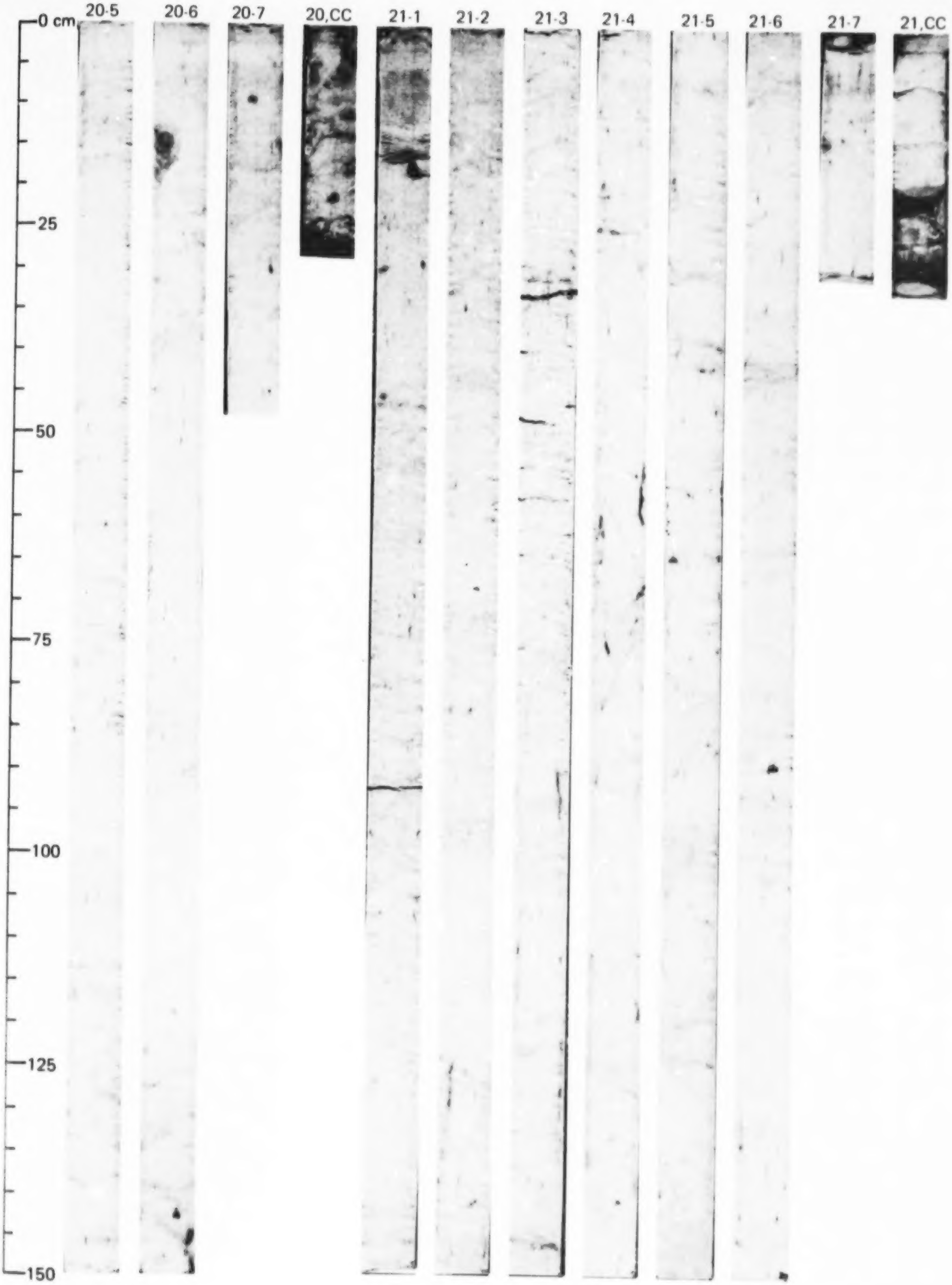
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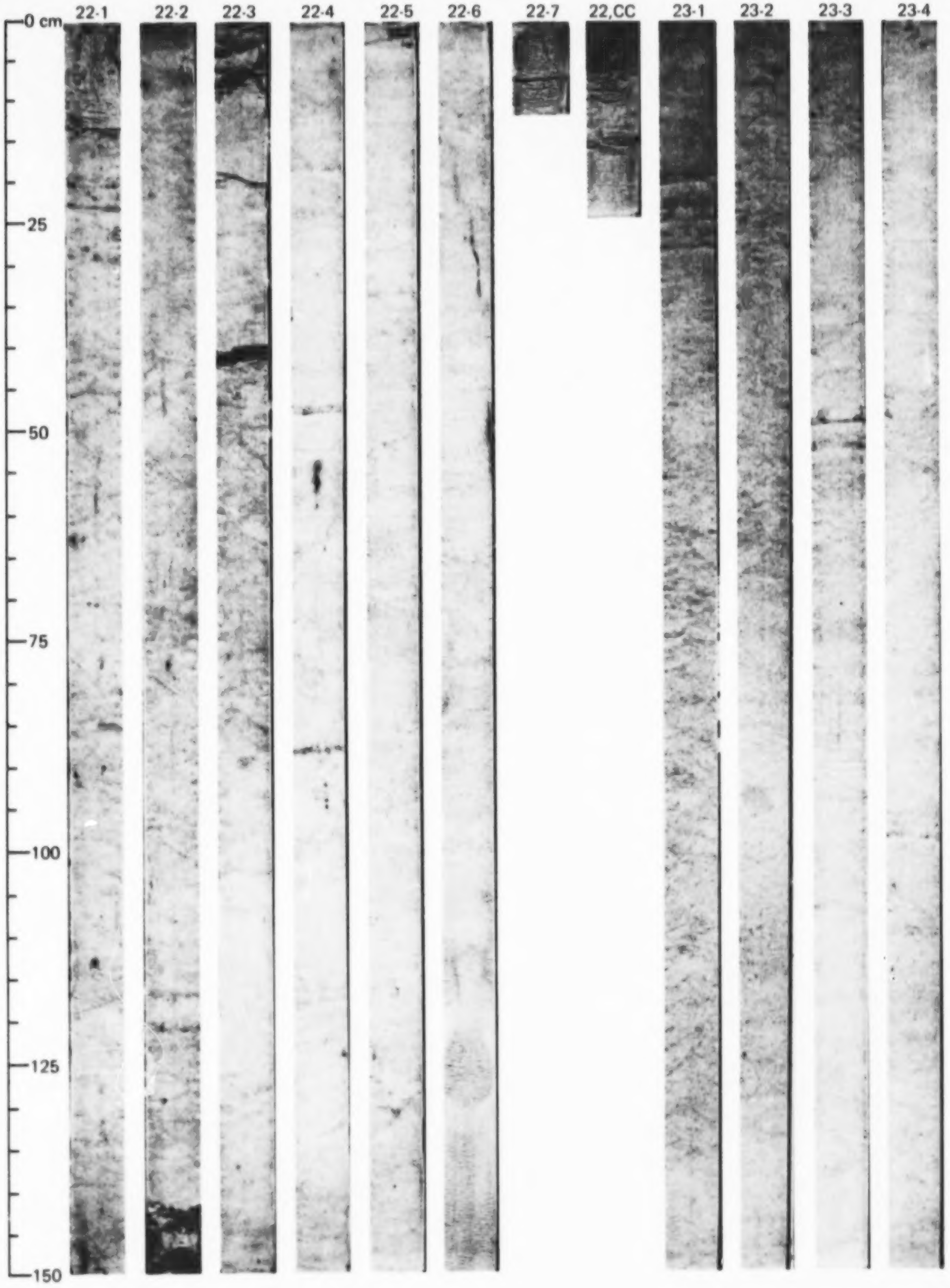
21,CC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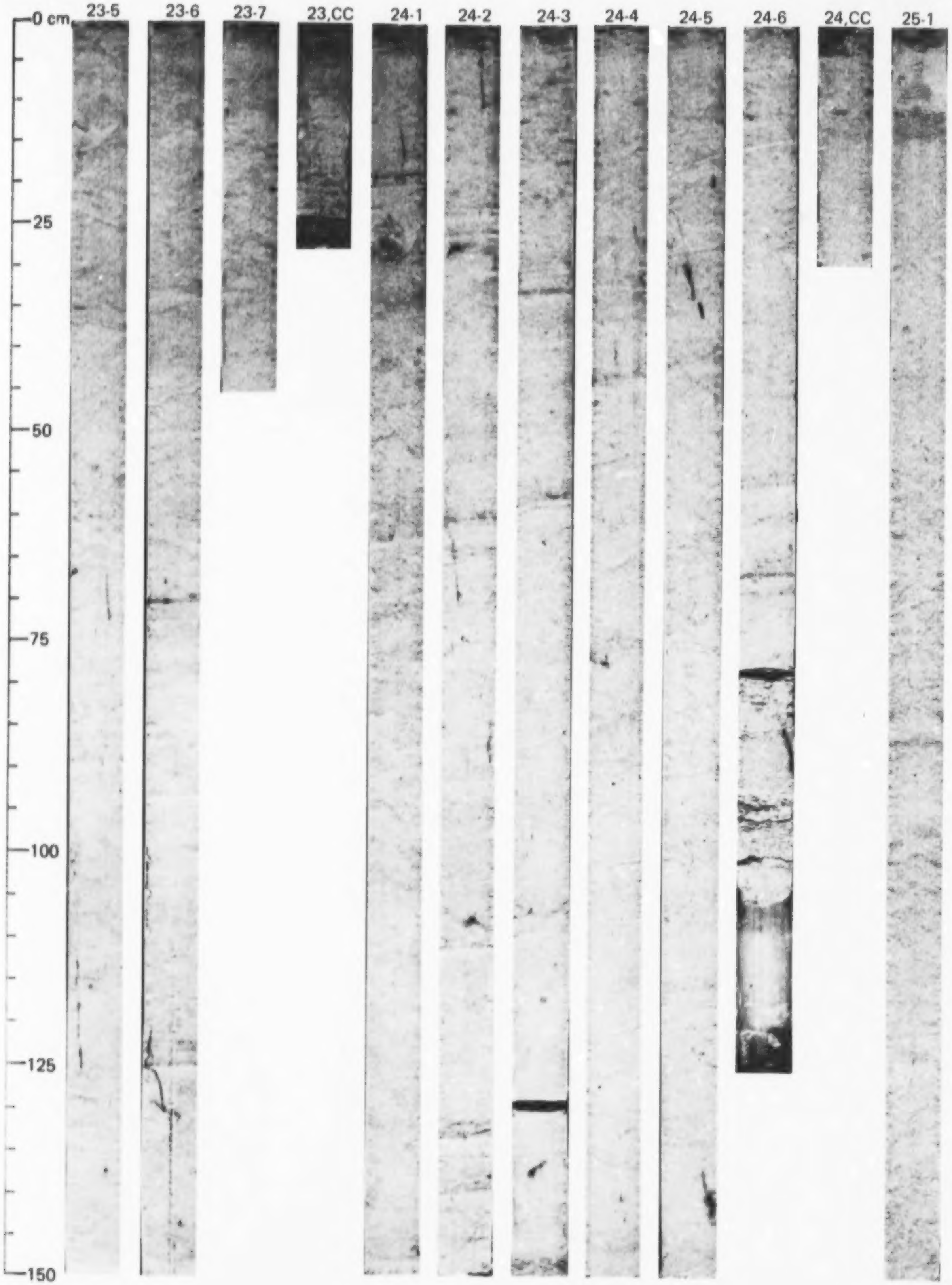
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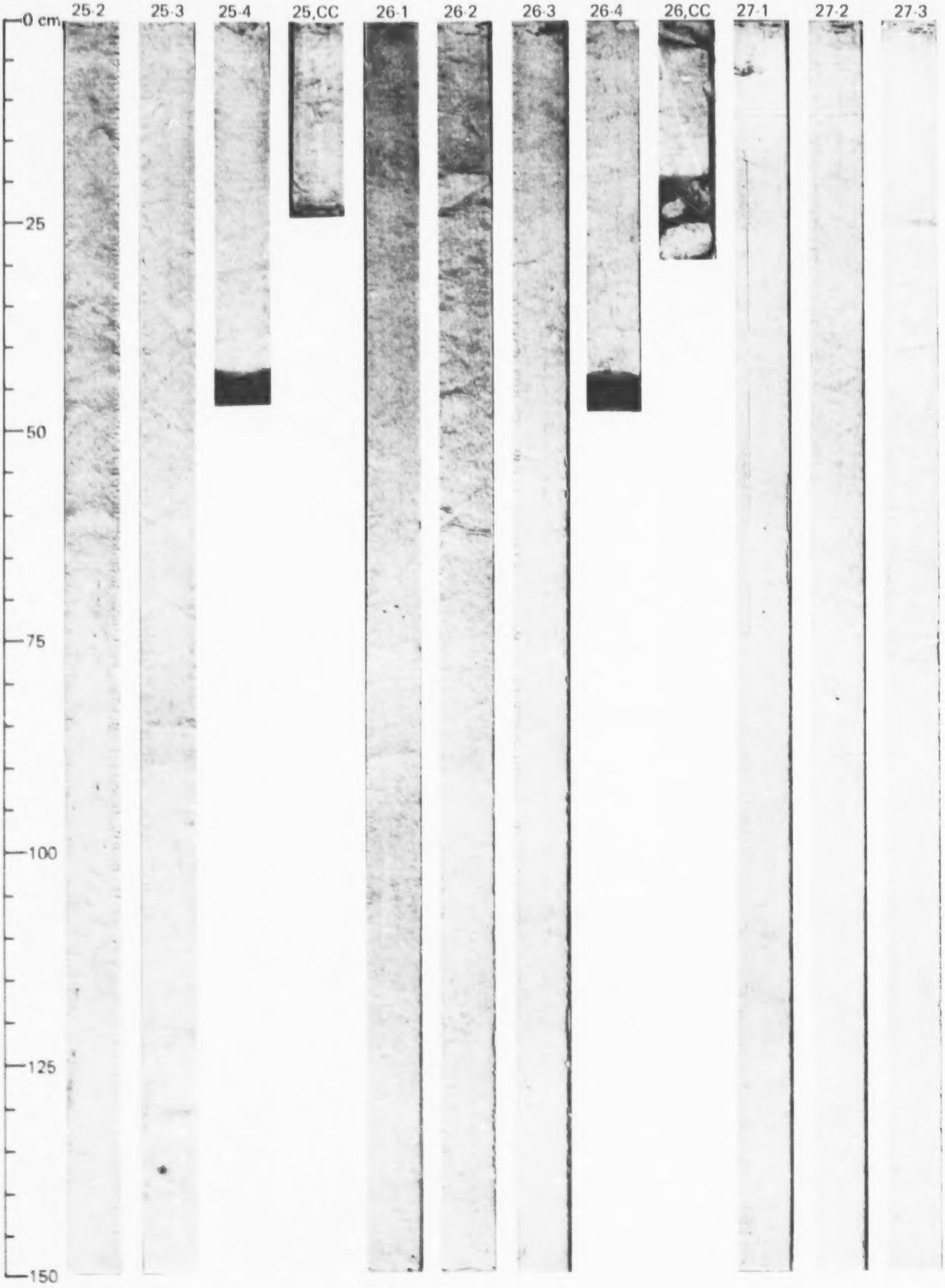
24,CC
25-1


25-2
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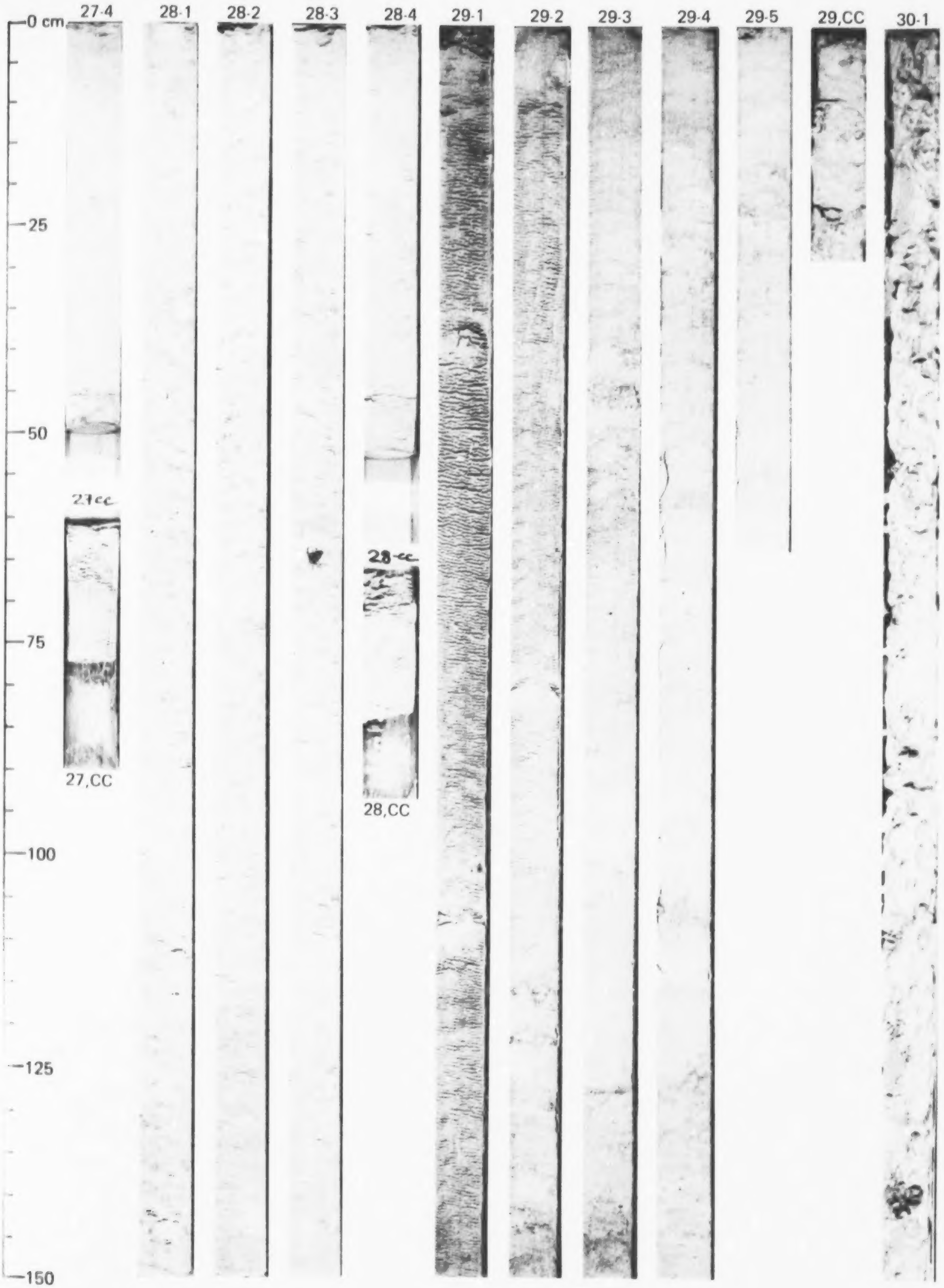
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30-1
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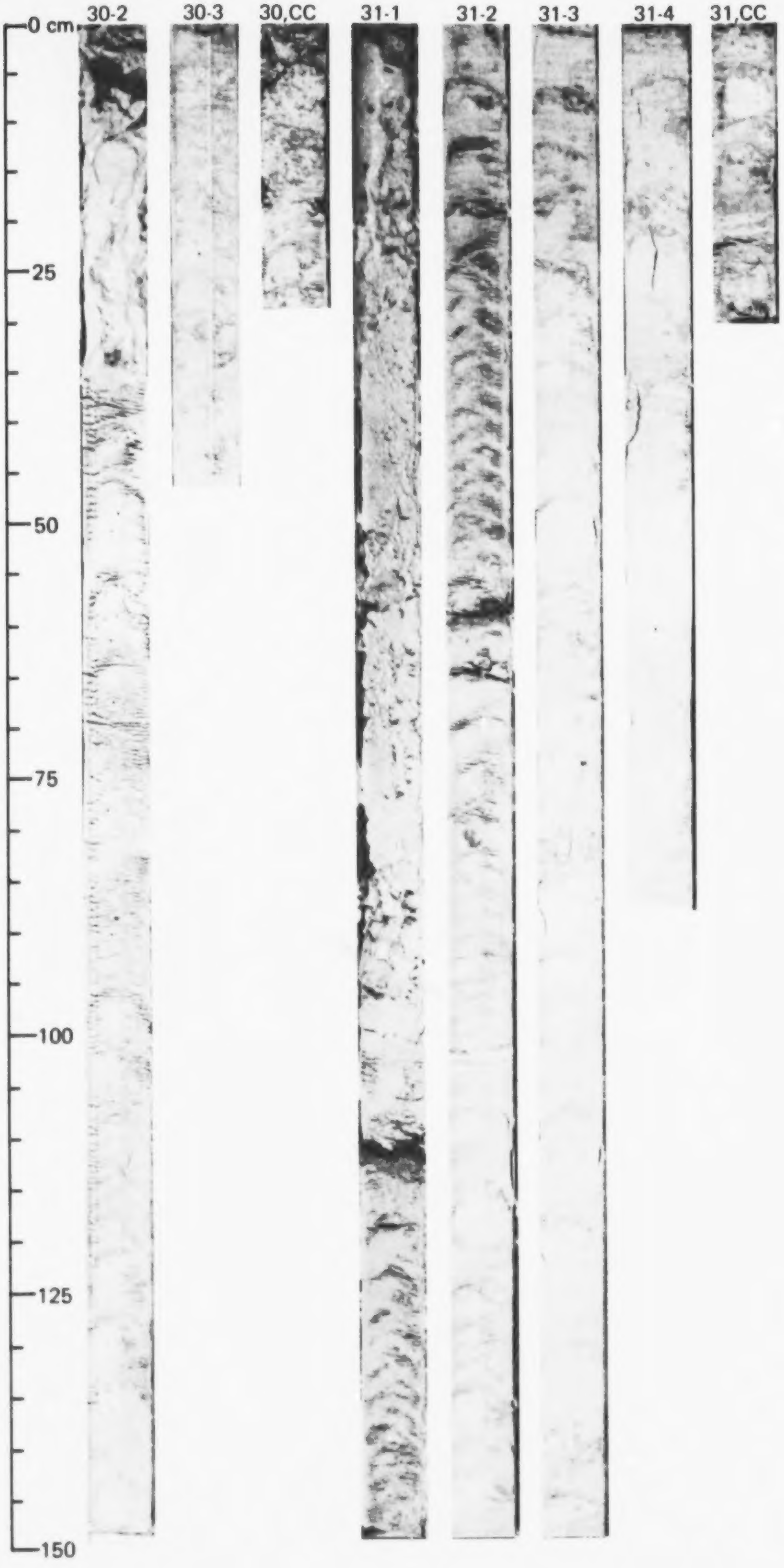
28-cc
28,CC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31-4
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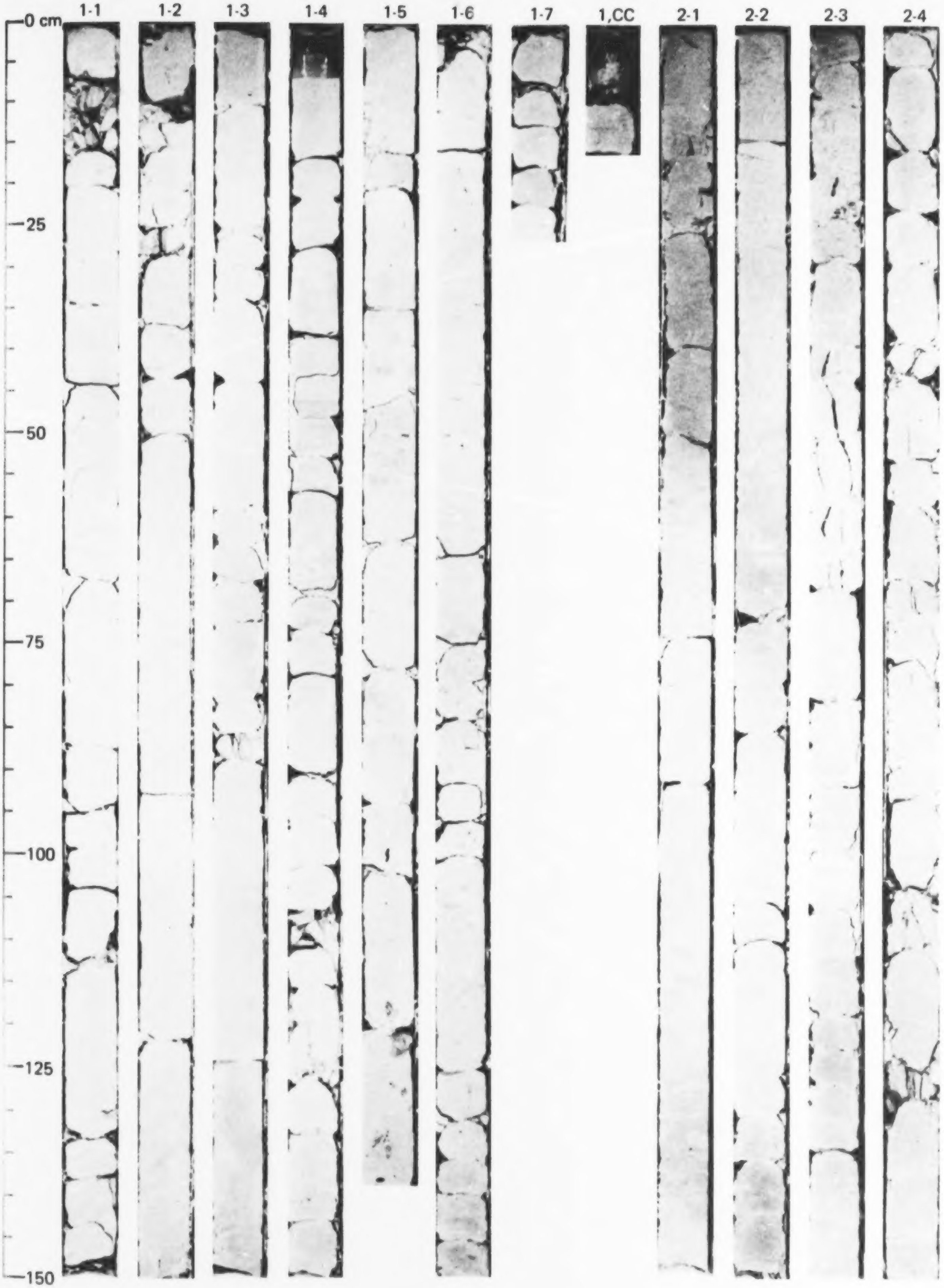
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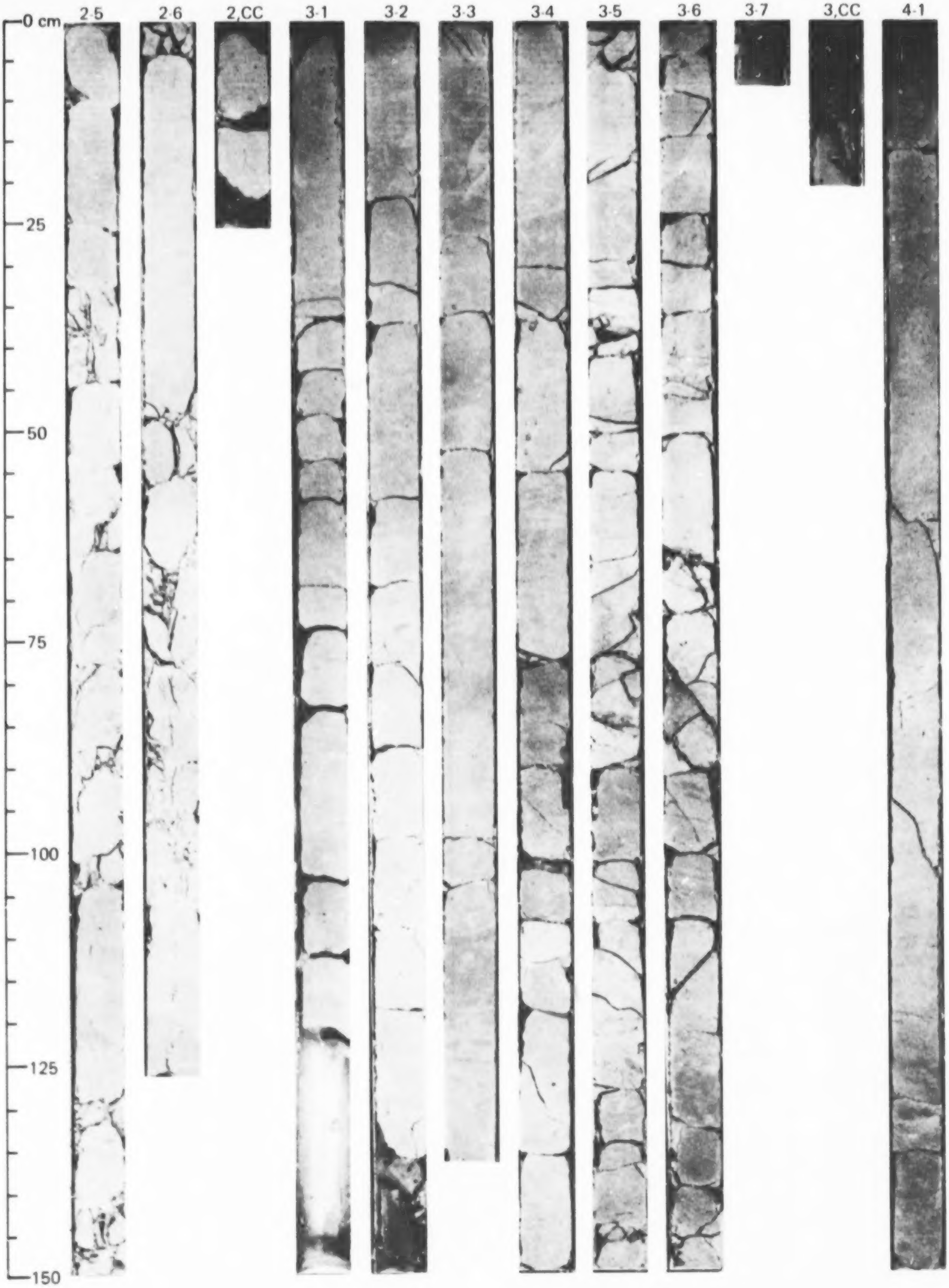
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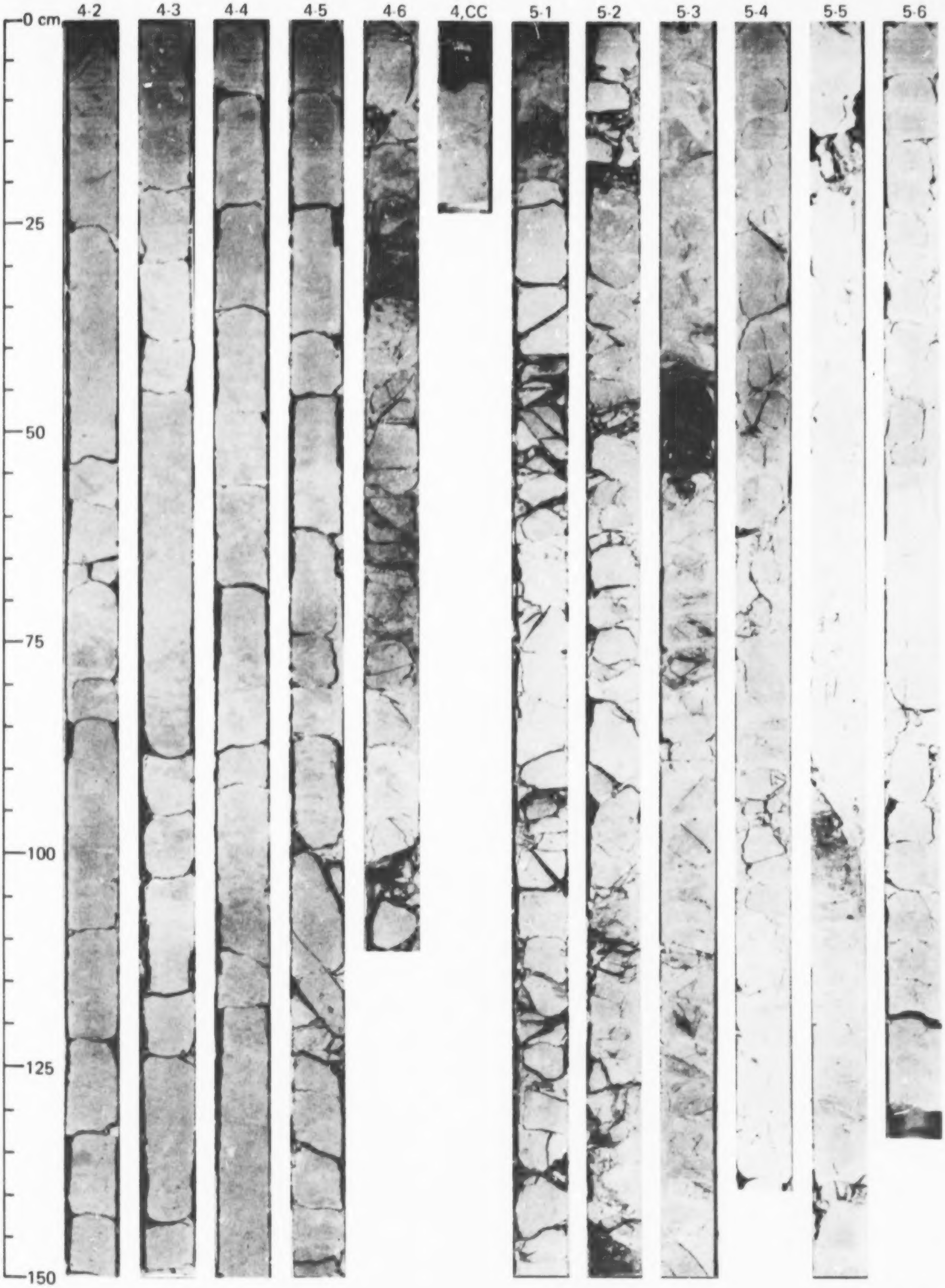
3,CC
4-1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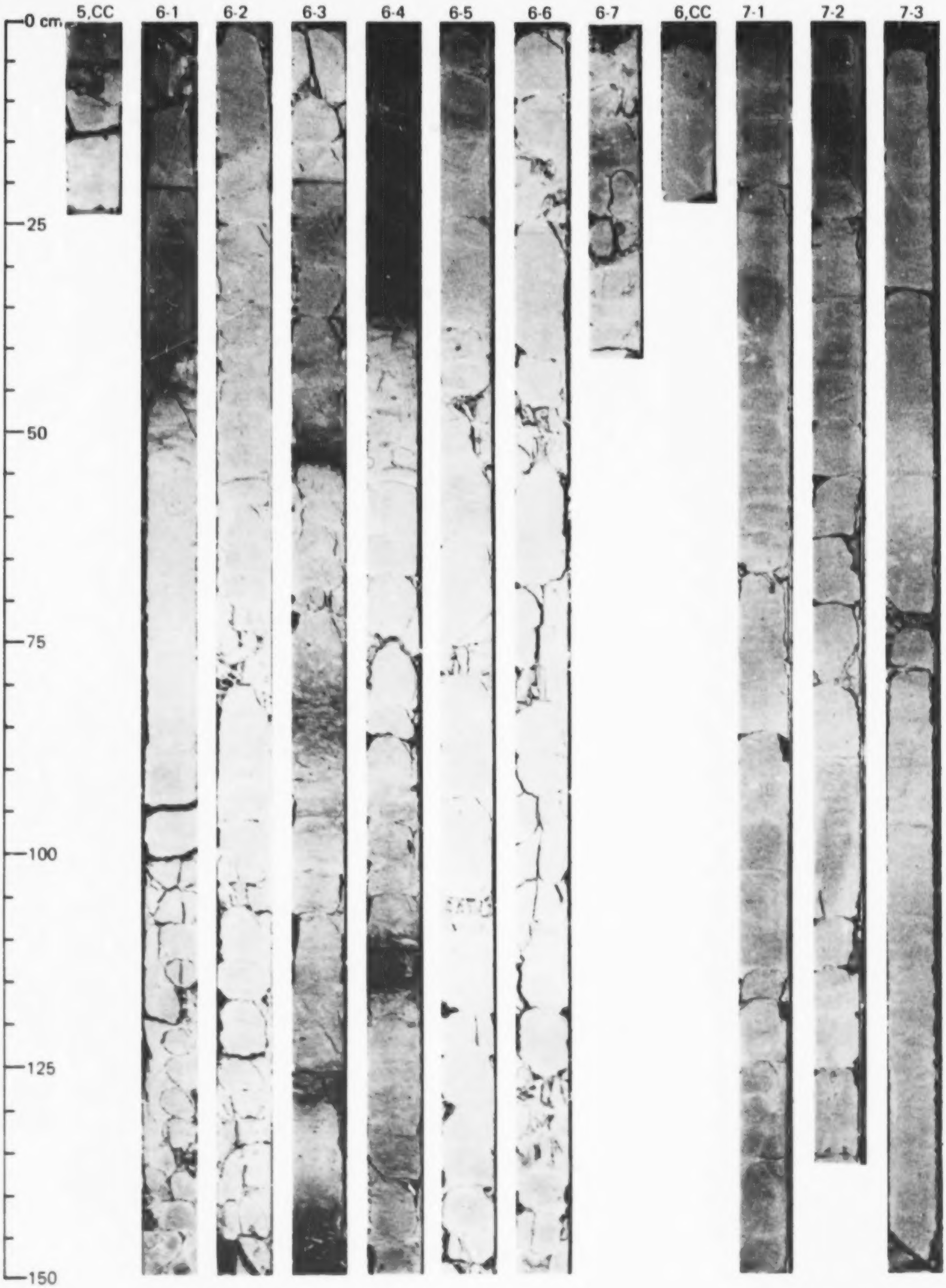
5,CC
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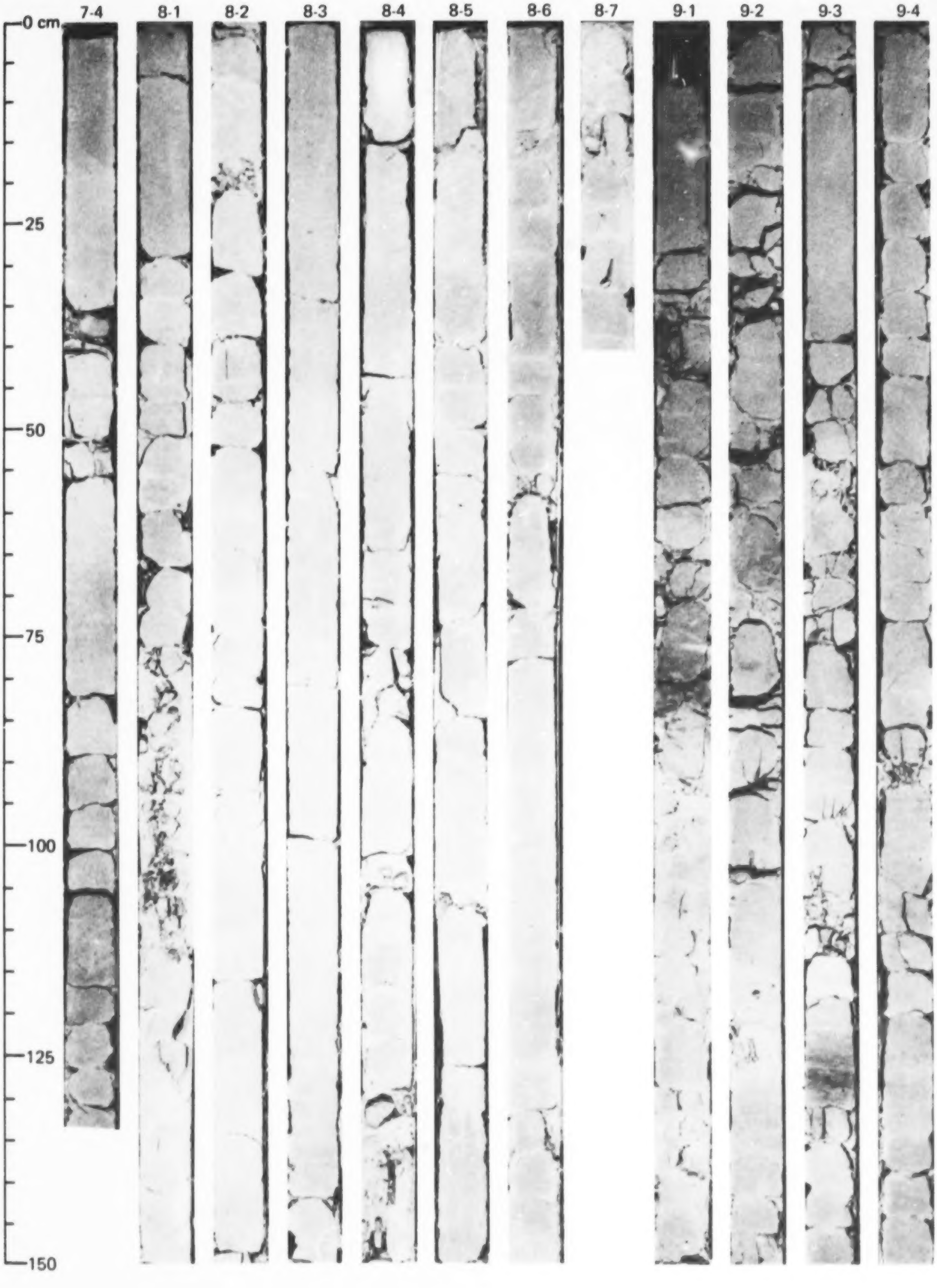
7-4
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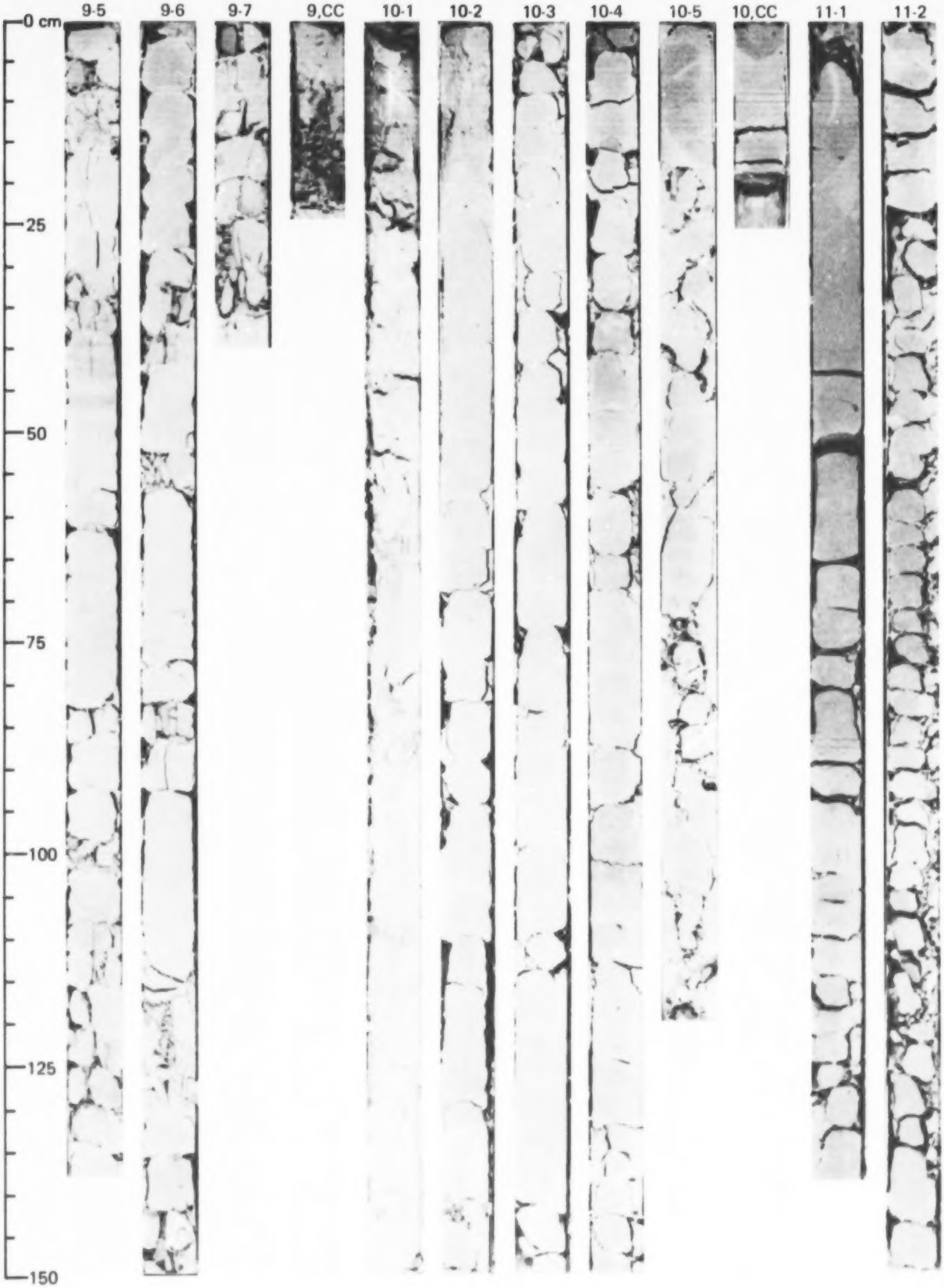
9-5
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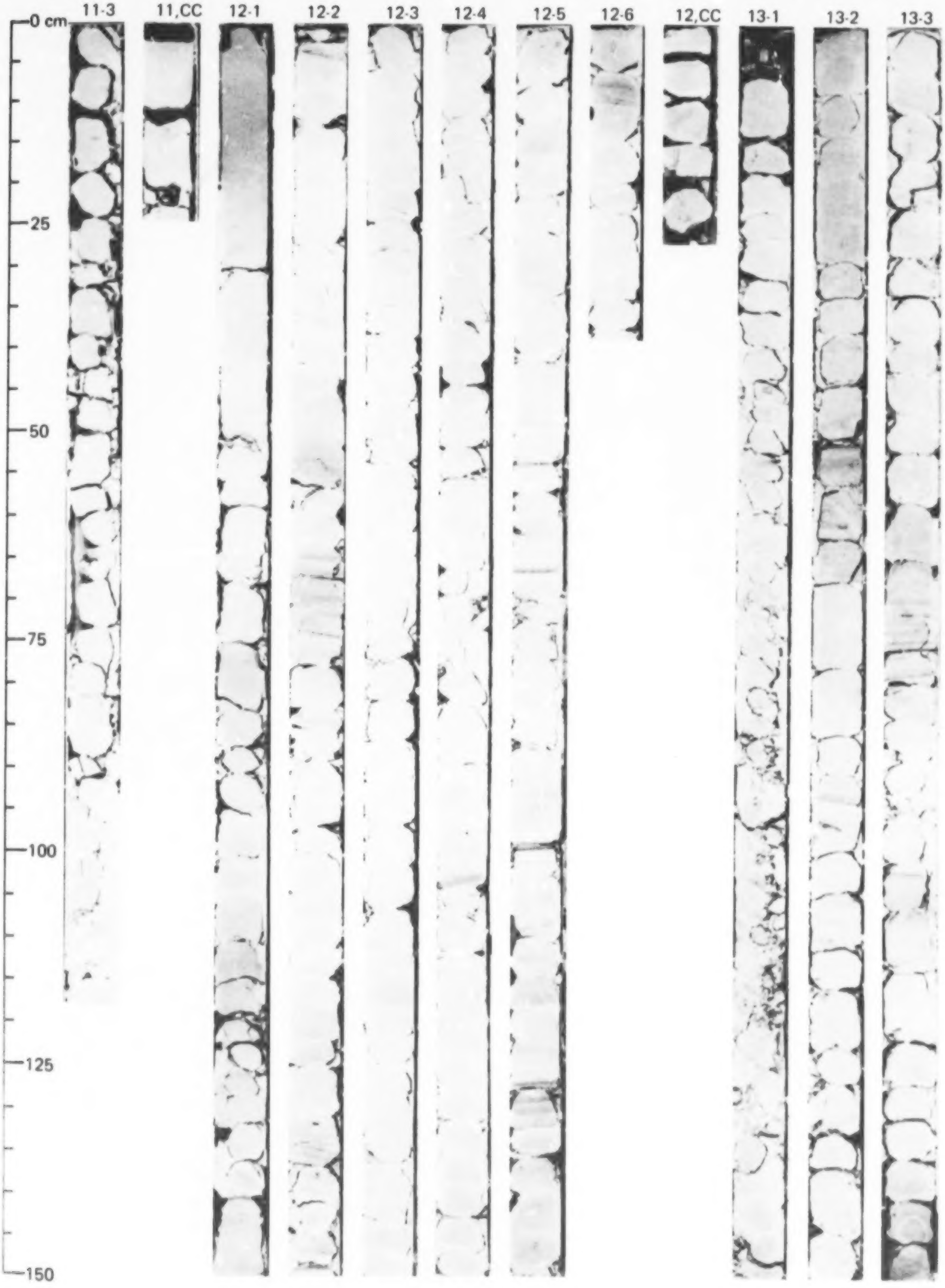
11-3
11,CC
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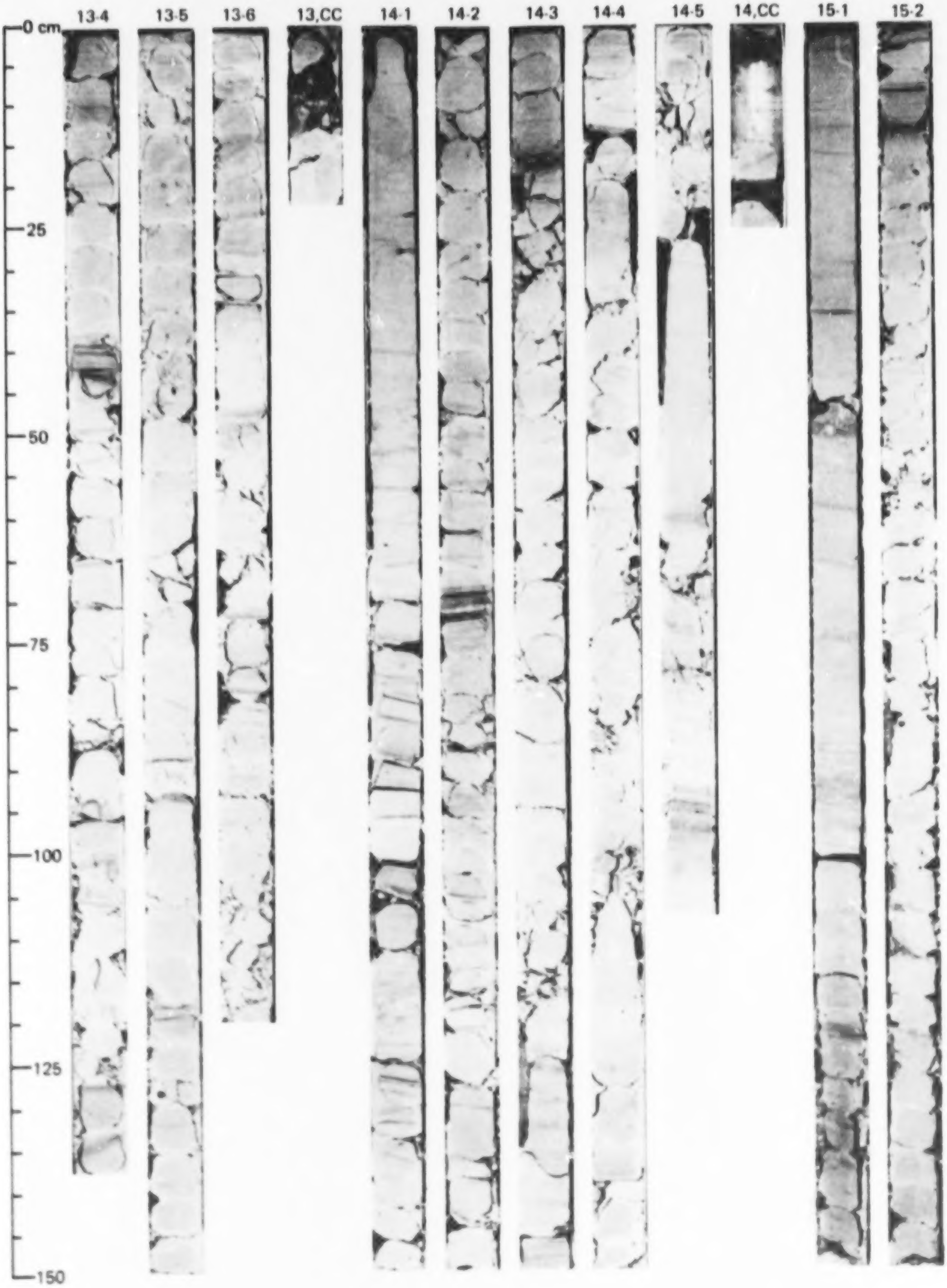
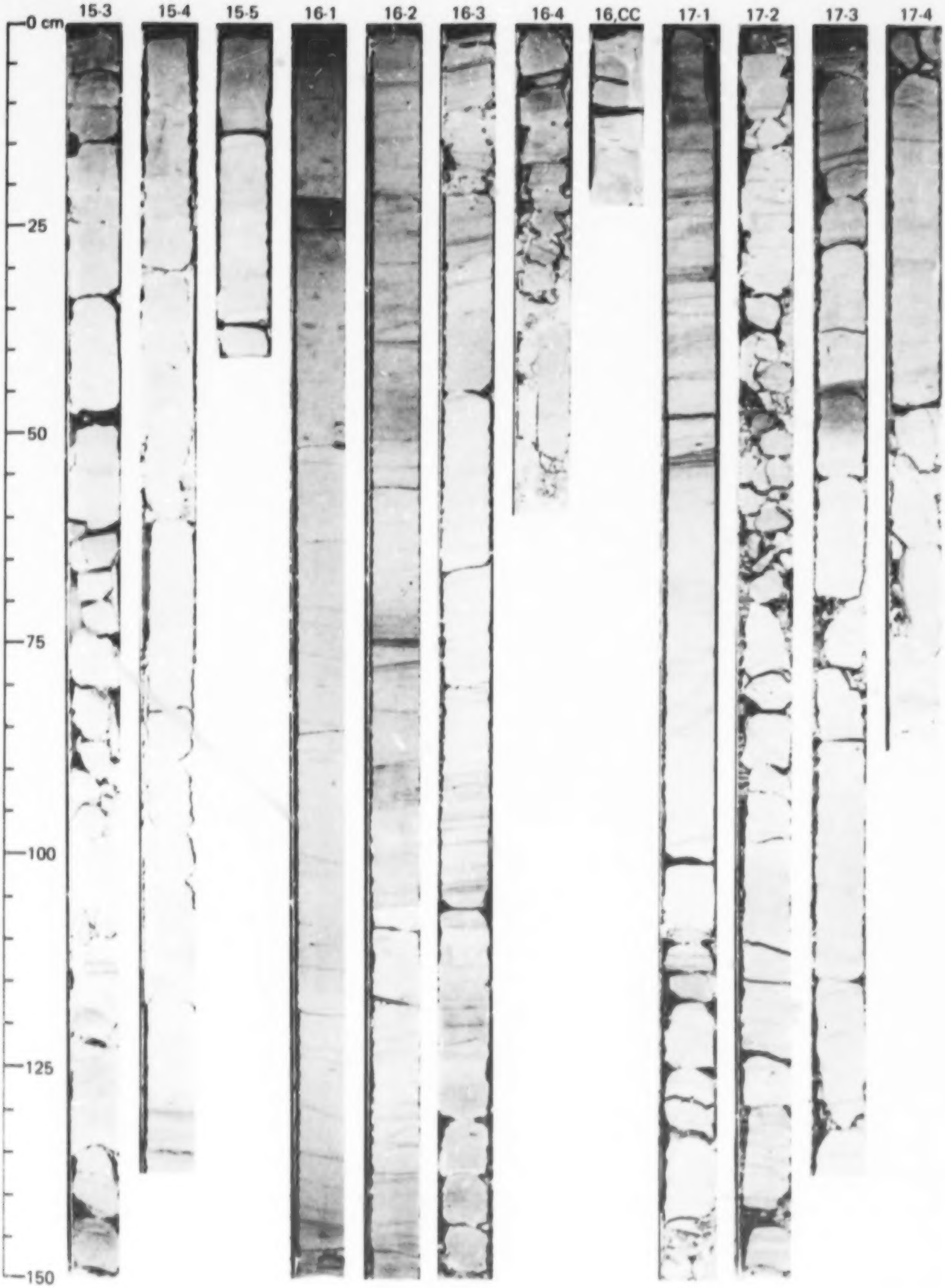
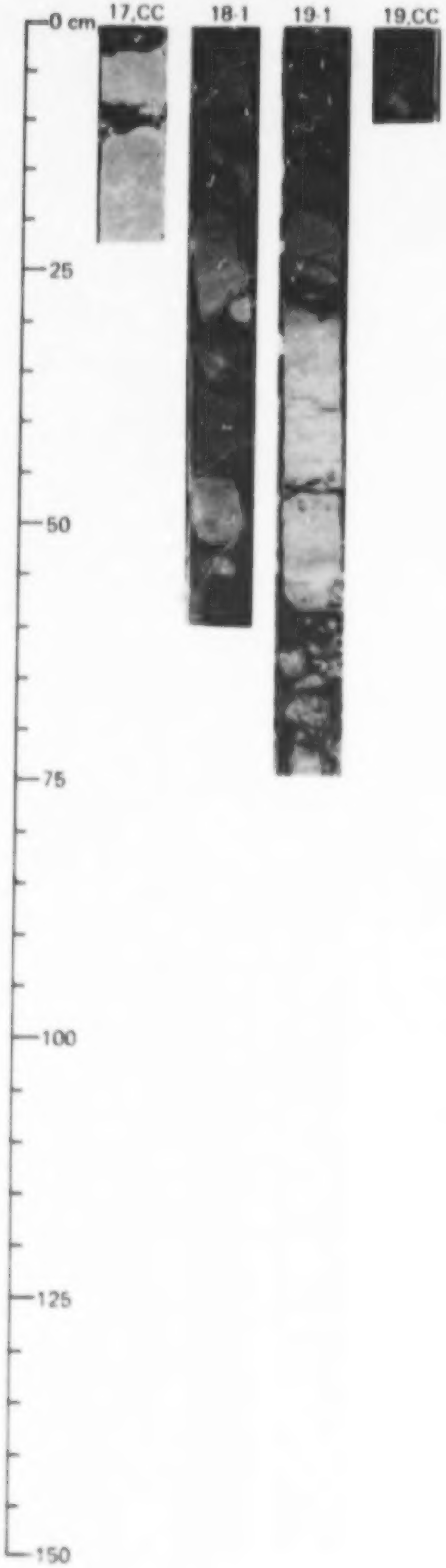
125
150


13-4
13-5
13-6
13,CC
14-1
14-2
14-3
14-4
14-5
14,CC
15-1
15-2
0 cm
25
50
75
100
125
150


15-3
15-4
15-5
16-1
16-2
16-3
16-4
16,CC
17-1
17-2
17-3
17-4
0 cm
25
50
75
100
125
150


17,CC
18-1
19-1
19,CC
0 cm
25
50
75
100
125
150

5. SITE 589: LORD HOWE RISE, 30°S[1]

Shipboard Scientific Party[2]

HOLE 589

Date Occupied: 12 December 1982

Date departed: 13 December 1982

Time on hole: 15.5 hr.

Position: 30°42.72′S; 163°38.39′E

Water depth (sea level; corrected m, echo-sounding): 1391

Water depth (rig floor; corrected m, echo sounding): 1401

Bottom felt (m, drill pipe): 1398.3

Penetration (m): 36.1

Number of cores: 4

Total length of cored section (m): 36.1

Total core recovered (m): 35.08

Core recovery (%): 97.2

Oldest sediment cored:
  Depth sub-bottom (m): 36.1
  Nature: Foraminifer-nannofossil ooze
  Age: Quaternary

Basement: Not reached

Principal results: The objectives of Site 589 are those that were eventually fulfilled at Site 590, which is slightly to the south on the Lord Howe Rise. The shipboard positioning computer system failed after only four Quaternary to latest Pliocene HPC cores had been taken, to a total sub-bottom depth of 36.1 m. The section has a clear paleomagnetic polarity stratigraphy from the Brunhes Chron to the upper part of the lower Matuyama Chron. The extrapolated age for the base of the core is 2 m.y., based on an overall sedimentation rate of 18 m/m.y. The section consists of a veneer (0–0.4 m) of orange-colored foraminifer-nannofossil ooze (Subunit IA) underlain by lighter-colored Quaternary foraminifer-nannofossil ooze to nannofossil ooze (Subunit IB) to the base of the cored sequence. This unit exhibits alternations between lighter greenish intervals richer in volcanic ash and those of white to light gray ooze with less important ash. Foraminifers and calcareous nannofossils are well preserved.

OBJECTIVES

Site 589 occurs in the central part of the Lord Howe Rise (30°42′S) to the east of the crest at a water depth of 1391 m (Figs. 1 and 2). Initially, this site was selected to obtain a continuous, high-resolution Neogene–late Paleogene sequence in the transitional water mass and at relatively shallow depths as part of a vertical profile. Unfortunately the objectives were not met at this site because the onboard positioning computer failed during drilling, and the hole was terminated. Only four Quaternary cores were taken. Because of the failure of the computer, to help preserve remaining time on the cruise it was decided to core a new site (Site 590) further to the south, in the same geological setting and with the same objectives. Therefore, objectives originally intended for Site 589 are discussed in more detail in the Site 590 site chapter.

OPERATIONS

Site 588 to Site 589

Transit between sites was completely routine. Fair weather and a following current combined to help the vessel average 10.3 knots for the 304.3 mi. distance. The ship made directly for the coordinates of the site specified in the scientific prospectus. Precise site selection and preliminary surveying were not required, so the beacon (16

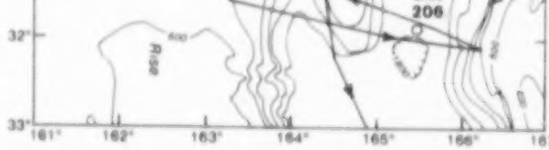


Figure 1. Regional bathymetry (fathoms) around Site 589; after Mammerickx (1974); *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Figure 2.

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), School of Earth Sciences, Flinders University of South Australia, Bedford Park, South Australia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; Charles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, P.O. Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, Stony Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National d'Histoire Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Sciences Division, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 96720; James V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Sciences, Open University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United Kingdom; William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, Littleton, CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgang-Goethe Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic of Germany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Oceanography, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, College Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. Geological Survey, Denver Federal Center, Denver, CO 80225); Cambell S. Nelson, Department of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Christian Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 13288 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu University, Varanasi 221 005, India; Rudiger Stein, Geologisch-Paläontologisches Institut, Universität Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petroleum and Organic Geochemistry (ICH-5), Kernforschungslage Julich GmbH, P.O. Box 1913, 5170 Julich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, Faculty of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

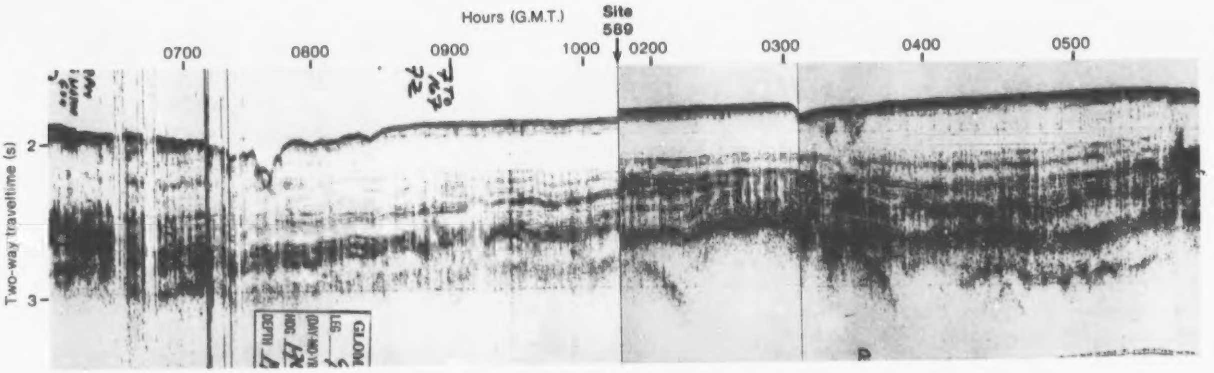


Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 589; bandpass filter 40–160 Hz.

kHz) was dropped on the first pass at 2110 hr., 12 December 1982.

Site 589: Central Lord Howe Rise

The vessel was steadied over the beacon with some difficulty owing to a bad combination of wind, current, and swell coming from three different directions. Nonetheless, the pipe trip commenced at 2255 hr. A combination short hook-up bottom-hole assembly (BHA) for both piston coring (HPC) and extended core barrel (XCB) coring was again used. The bit was lowered to 1396 m and the first 9.5 m variable-length (VL) HPC was shot at 0338 hr., 13 December, recovering 7.3 m of sediment at the mud line and officially spudding Hole 589 (Table 1). Water depth was thus determined to be 1398 m by drill pipe measurement. Four 9.5 m VLHPC cores were taken, including a successful Von Herzen heat flow measurement with Core 589-4.

As Core 5 was about to be shot, the Dynamic Positioning Computer broke down entirely. Within minutes, it became clear that the vessel had probably taken a severe offset, because the computer was providing no position reference information which could be used for manual positioning. The rig crew was given orders to recover the core barrel and immediately pull the pipe clear of the mud line. The mud line was cleared 30 min. after the computer had failed. One hour and 45 minutes after clearing the mudline the positioning computer still was not functioning so the drill string was tripped for safety. The bit arrived on deck at 1230 hr. Inspection of the drill string as it came on deck showed that no damage had been done to the pipe or BHA. Since the computer was still down at this time and the probability of an immediate repair was low, the decision was made to leave for an alternate site to the south, some 8 hr. distant. The vessel was underway for the alternate site at 1239 hr. 13 December 1982.

Table 1. Coring summary, Site 589.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top	Bottom	Depth below seafloor (m) Top	Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
1	13	0410	1398.3–1405.6		0.0–7.3		7.3	7.26	99.4
2	13	0450	1405.6–1415.2		7.3–16.9		9.6	9.53	99.2
3	13	0535	1415.2–1424.8		16.9–26.5		9.6	9.39	97.8
4	13	0625	1424.8–1434.4		26.5–36.1		9.6	8.90	92.7
							36.1	35.08	97.2

LITHOSTRATIGRAPHY

Site 589 consists of one hole that was cored continuously with the HPC from 0 to 36.1 m sub-bottom. The recovered sediment sequence consists of one lithostratigraphic unit which can be divided into two subunits, distinguished by color, grain size, and composition.

Subunit IA (0 to 0.4 m sub-bottom, late Pleistocene) is a foraminifer–nannofossil ooze of grayish orange color. The grain size of Subunit IA is coarser than the remainder of the sediment sequence. The color change that separates Subunit IA from the underlying Subunit IB is a boundary that separates an upper oxidized and a lower reduced facies. The oxidized zone corresponds to Subunit IA in most other sites drilled during Leg 90.

Subunit IB (0.4 to 36.1 m sub-bottom, early Pleistocene) varies from foraminifer–nannofossil ooze to nannofossil ooze with colors of light greenish gray and pale olive to white and very light gray. Noncarbonate components observed in smear slides (see Figure 3) include traces of quartz, feldspar, heavy minerals, and sponge spicules. Volcanic glass and pyrite occur in abundances from traces up to 5%. Burrows are apparent at irregular intervals throughout this unit. Iron sulfide minerals periodically occur as dark spots and streaks throughout the entire unit.

The greenish parts of Subunit IB are characterized by a higher content of both foraminifers and volcanic glass. There appears to be a cyclic alternation between intervals of greenish sediment and intervals of white to light gray sediment. At least 39 of these "color cycles" with an average thickness of 0.9 m can be distinguished in the 36.1 m sequence of Site 589.

SEISMIC STRATIGRAPHY

Figure 4 illustrates a portion of the shipboard water gun seismic profile collected during the approach to Site 589. The uppermost two acoustic units, A and B, are directly comparable to those described for Site 588.

Site 589 was drilled to a total depth of 36.1 m, entirely within the uppermost portion of acoustic Unit A. I comprises the two lithostratigraphic subunits, IA and IB described in the preceding section.

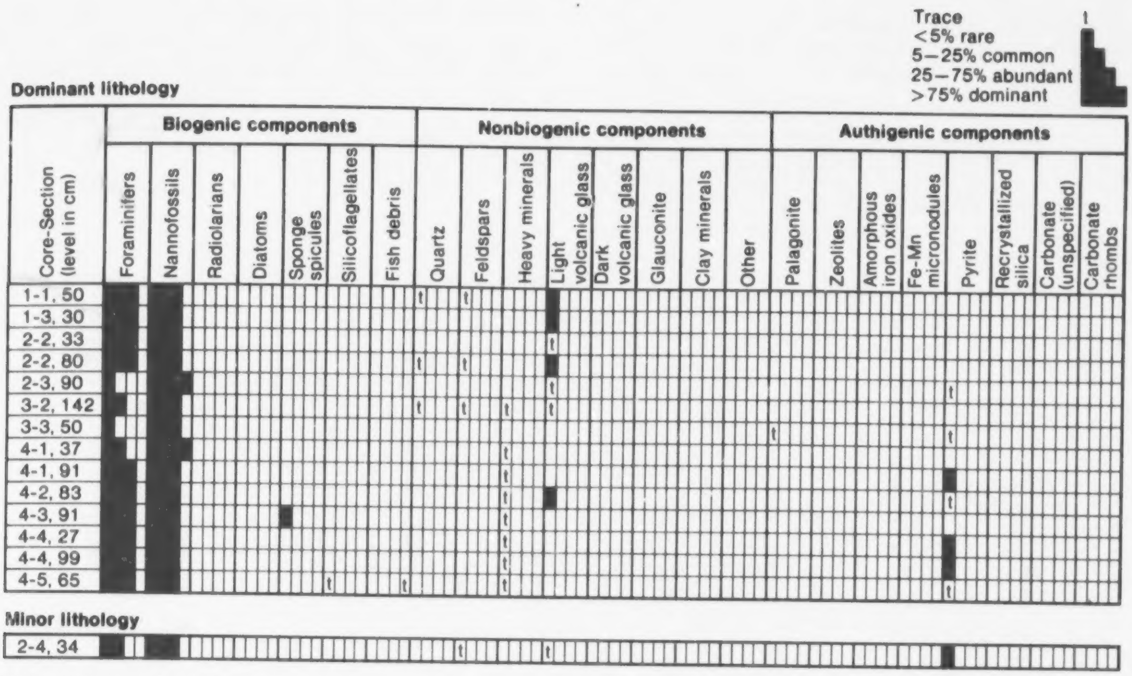


Figure 3. Smear slide summary, Site 589.

BIOSTRATIGRAPHY

Abundant and well-preserved foraminifers and calcareous nannoplankton of Quaternary to latest Pliocene age were recovered from the samples. Some tephra-glass shards were encountered in Core 589-2. Radiolarians, diatoms, and silicoflagellates were not found. For biostratigraphic correlation, see Figure 5.

Foraminifers

Planktonic Foraminifers

Four core-catcher samples were examined for foraminifers. The four cores (36.1 m) belong to the *Globorotalia truncatulinoides* Zone and the *G. truncatulinoides–G. tosaensis* overlap Zone. The fauna, besides the zonal marker, includes *Globorotalia inflata, Pulleniatina obliquiloculata, Neogloboquadrina dutertrei, Globigerinoides ruber, Globigerinoides conglobalus*, and *Globigerina bulloides. Globorotalia tumida* is rare to frequent, whereas *Sphaeroidinella dehiscens* is very rare. *G. tosaensis* is recorded in Cores 589-2 to 589-4.

Benthic Foraminifers

Benthic foraminifers were examined in the >63μm fraction from Core 589-1 to 589-4,CC at Site 589. All samples are well preserved and benthics are frequent. The species change little through the four Quaternary samples: most common are *Uvigerina peregrina, U. hispido-costata, Melonis barleeanum, Cassidulina laevigata carinata, Heterolepa kullenbergi, Stilostomella lepidula, Cibicides wuellerstorfi*, and *Oridorsalis umbonatus*. Glacial–interglacial cycles may be discernible in the alternating abundance peaks of *U. peregrina* and cibicides plus *Cassidulina carinata*.

Calcareous Nannoplankton

Some reworking of both Pleistocene and late Pliocene nannoplankton occurs throughout the four cores. Samples 589-1-1, 0–1 cm and 589-1-2, 0–1 cm contain abundant *Emiliania huxleyi* and are placed in the late Pleistocene *Emiliania huxleyi* Zone (NN21). Sample 589-4,CC contains common *Discoaster brouweri* and probably should be placed in the latest Pliocene *Discoaster brouweri* Zone (NN18). The zonal boundary (NN20/NN19) cannot be recognized.

Of some interest are fluctuations of *Scyphosphaera* species, which are fairly common in levels 589-4-5, 589-3,CC to 589-3-5, and 589-2-3.

PALEOMAGNETISM

Paleomagnetic properties of the short sequence recovered were similar to those for Site 588. An upper zone of a few meters of slightly oxidized brownish sediment gave relatively strong intensities (typically 2 μG). Below Core 589-1 the sediment is whiter, with gray streaks and patches (attributed to iron sulfides) and intensities of about 0.1 μG.

Shore-based NRM measurements on two specimens per section defined a clear polarity stratigraphy (Fig. 6). The Jaramillo Event is not recorded. The inferred over-

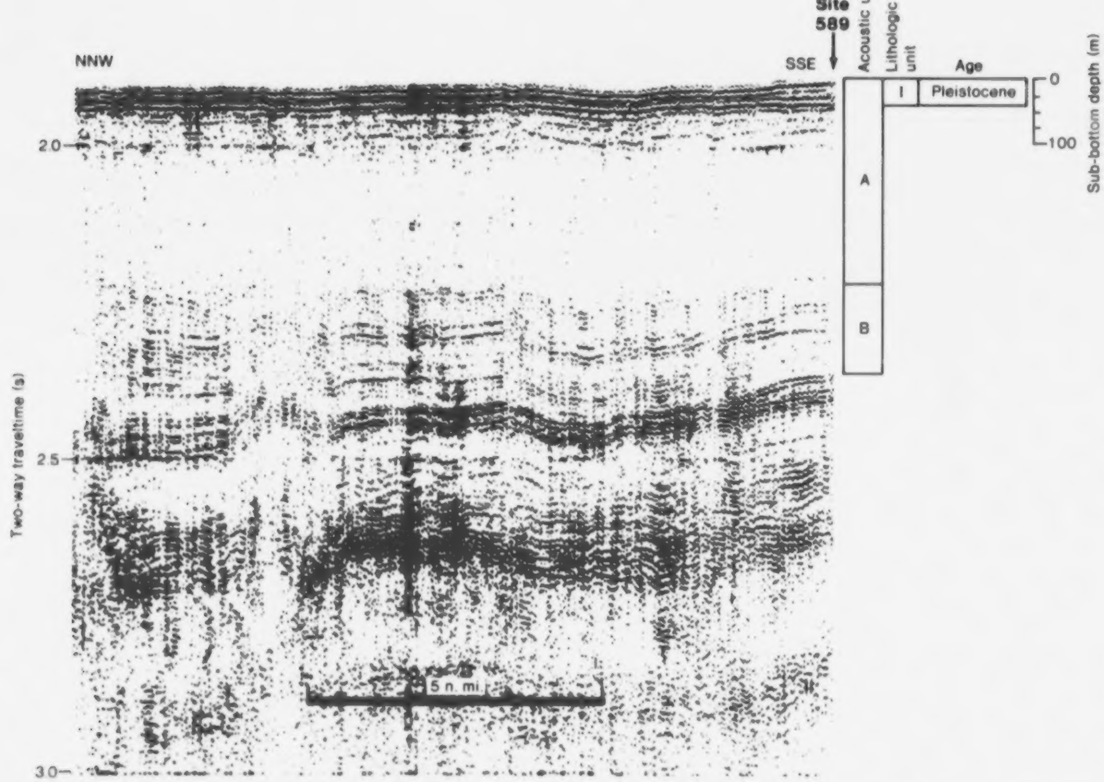


Figure 4. Comparison of acoustic Unit A with lithological Unit I cored at Site 589; shipboard water gun seismic profile collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 2000 m/s.

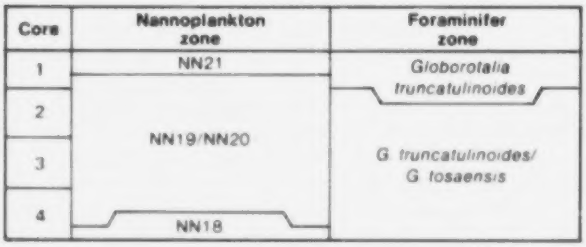

Core
Nannoplankton zone
Foraminifer zone
1
2
3
4
NN21
NN19/NN20
NN18
Globorotalia truncatulinoides
G. truncatulinoides/ G. tosaensis

Figure 5. Biostratigraphy of Site 589. Section barren of radiolarians.

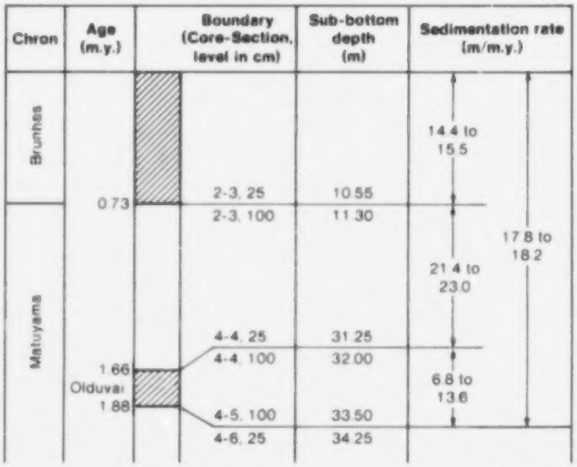

Chron
Age (m.y.)
Boundary (Core-Section, level in cm)
Sub-bottom depth (m)
Sedimentation rate (m/m.y.)
Brunhes
Matuyama
0.73
1.66
Olduvai
1.88
2-3, 25
2-3, 100
4-4, 25
4-4, 100
4-5, 100
4-6, 25
10.55
11.30
31.25
32.00
33.50
34.25
14.4 to 15.5
21.4 to 23.0
6.8 to 13.6
17.8 to 18.2

Figure 6. Paleomagnetic stratigraphy for Hole 589 based on NRM data. Estimated bottom age is 2 m.y. The Jaramillo Subchron is not resolved.

all sedimentation rate is 18 m/m.y. Statistics for this data set are:

Geometric mean intensity = 0.159 μG
Scalar mean inclination = 5.7 ±48.6°s.d.
Axial dipole inclination = −49.9°
Mean angle between repeats = 3.0°

Shipboard long-core and subsample NRM measurements agreed with the interpretation of Figure 6 but were much less precise. No absolute orientation data were obtained. There are no prominent intensity spikes.

Initial shipboard measurements on fresh specimens from Cores 589-1 and 589-2 gave intensities which were typically two to three times higher than those recorded subsequently in the laboratory after storing samples for 6 mo. This was despite very careful precautions to minimize dessication. Corresponding changes in direction of remanence were not significant for determining polarity. Intensity decay during storage of wet sediments is quite common, though it is not usually so large as noted here. It seems unlikely that small changes in water content could have had such a pronounced effect. Thus the random dispersion of small interstitial grains, and perhaps post-coring diagenesis, may also play important roles.

SUMMARY AND CONCLUSIONS

Coring at Site 589 was a disappointment because failure of the onboard ship-positioning computer forced abandonment of the hole. It was decided to move to a new location (Site 590) further south in order to save some of the lost time.

The four cores obtained provide a Quaternary to latest Pliocene sediment record 36.1 m in thickness. The section exhibits a clear polarity stratigraphy from the Brunhes Chron to the upper part of the Matuyama Chron. The extrapolated age for the base of the core is 2 m.y., based on an overall sedimentation rate of 18 m/m.y. The base of the section contains both *Globorotalia truncatulinoides* and *G. tosaensis* and Pliocene calcareous nannofossils. The sequence contains rich and well-preserved calcareous microfossils.

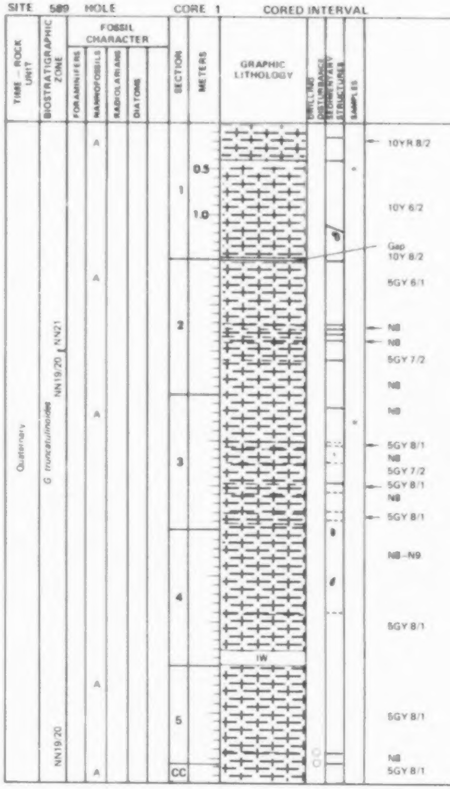
The sediment section consists of a veneer (0–0.4 m) of orange-colored foraminifer–nannofossil ooze (Subunit IA) underlain by lighter-colored Quaternary foraminifer–nannofossil ooze to nannofossil ooze (Subunit IB) to the base of the cored sequence. This unit exhibits alternations between lighter greenish intervals and white to light gray ooze.

REFERENCE

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports, Scripps Institution of Oceanography, La Jolla, California.

Date of Acceptance: 1 December 1983

SITE 589 HOLE CORE 1 CORED INTERVAL



TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19/20
NN21
NN19/20
A
A
A
A
A
1
2
3
4
5
CC
0.5
1.0
IW
10YR 8/2
10Y 6/2
Gap
10Y 8/2
5GY 6/1
N8
N8
5GY 7/2
N8
N8
5GY 8/1
N8
5GY 7/2
5GY 8/1
N8
5GY 8/1
N8–N9
5GY 8/1
5GY 8/1
N8
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, soft, grayish orange (10YR 7/4) clearly coarser than the remainder of the core.

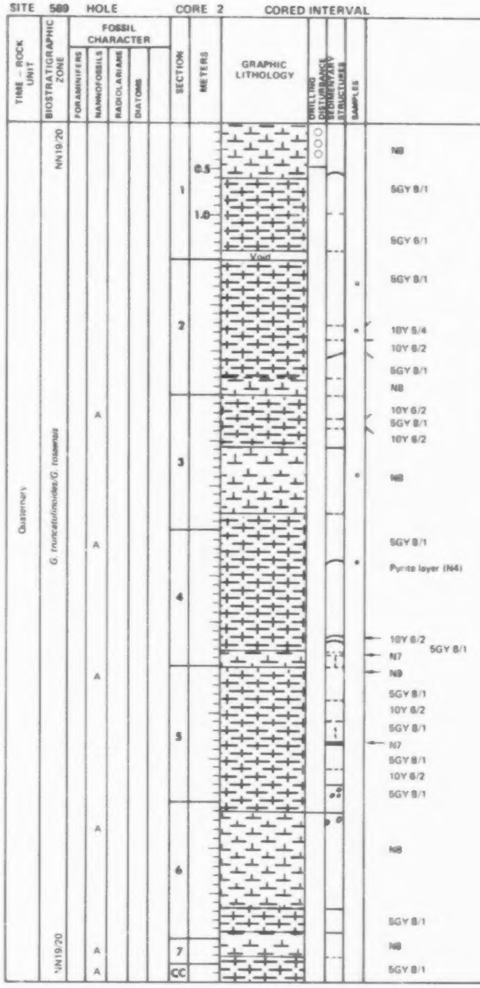
FORAMINIFER NANNOFOSSIL OOZE
Section 1: soft, to 120 cm pale olive (10Y 6/2), base pale greenish yellow (10Y 8/2) near 125 cm burrow (10Y 5/4), 136–145 gray spots (→iron sulfide).
Section 2–base: soft, white (N9) and very light gray (N8) to light greenish gray (5GY 8/1) color variations, gray (N6–N5) spots in white parts of the sections (→iron sulfide).

Greenish parts ←→ volcanic ash(?)

SMEAR SLIDE SUMMARY

	1, 50	3, 30
	D	D
Composition:		
Quartz	T	—
Feldspar	T	—
Volcanic glass	R	R
Foraminifers	A	A
Calc. nannofossils	A	A

SITE 589 HOLE CORE 2 CORED INTERVAL



TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19/20
NN19/20
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
5GY 8/1
5GY 6/1
5GY 8/1
10Y 5/4
10Y 6/2
5GY 8/1
N8
10Y 6/2
5GY 8/1
10Y 6/2
N8
5GY 8/1
Pyrite layer (N4)
10Y 6/2
5GY 8/1
N7
N9
5GY 8/1
10Y 6/2
5GY 8/1
N7
5GY 8/1
10Y 6/2
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, soft, light olive (10Y 5/4) to light greenish gray (5GY 8/1).

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5) spots→iron sulfide.

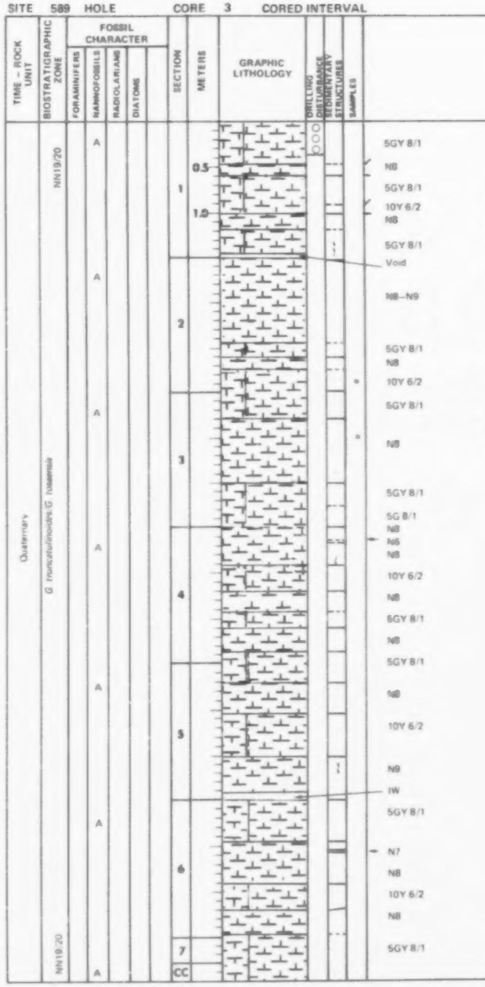
Cyclic(?) variations between FORAMINIFER NANNOFOSSIL OOZE (←→ volcanic ash?) and NANNOFOSSIL OOZE.

Burrowing apparent at irregular intervals.

SMEAR SLIDE SUMMARY:

	2, 33	2, 80	3, 80	4, 34
	D	D	D	M
Composition:				
Quartz	—	T	—	—
Feldspar	—	T	—	T
Volcanic glass	T	R	T	T
Pyrite	—	—	T	R
Foraminifers	A	A	R	C
Calc. nannofossils	A	A	D	A

SITE 589 HOLE CORE 3 CORED INTERVAL


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19/20
G. truncatulinoides/G. tosaensis
NN19/20
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5GY 8/1
N8
5GY 8/1
10Y 6/2
N8
5GY 8/1
Void
N8–N9
5GY 8/1
N8
10Y 6/2
5GY 8/1
N8
5GY 8/1
5G 8/1
N8
N6
N8
10Y 6/2
N8
5GY 8/1
N8
5GY 8/1
N8
10Y 6/2
N9
IW
5GY 8/1
N7
N8
10Y 6/2
N8
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, light greenish gray (5GY 8/1) to pale olive (10Y 6/2)

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8)

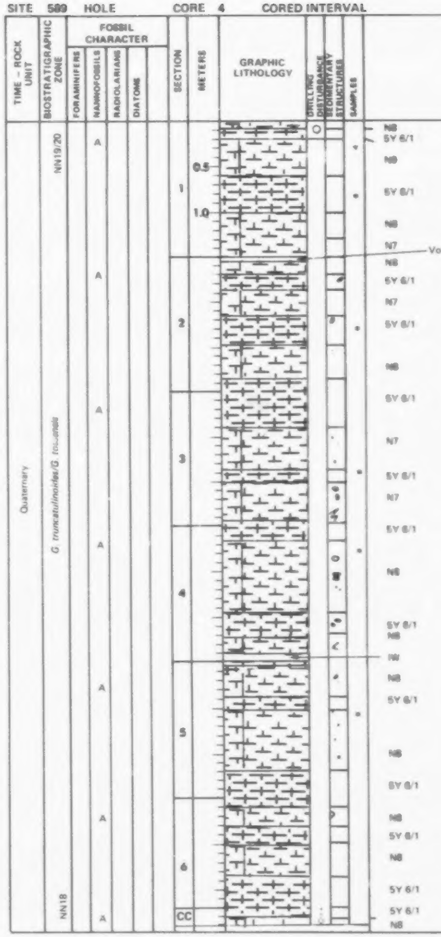
Dark (N6–N5) spots in the whole core

Cyclic variations between FORAMINIFER-BEARING NANNOFOSSIL OOZE (←→ + volcanic ash?) and NANNOFOSSIL OOZE.

SMEAR SLIDE SUMMARY

	2, 142	3, 50
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Heavy minerals	T	–
Volcanic glass	T	–
Palagonite	–	T
Pyrite	–	T
Foraminifers	C	R
Calc. nannofossils	A	D

SITE 589 HOLE CORE 4 CORED INTERVAL


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19/20
G. truncatulinoides/G. tosaensis
NN18
A
A
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5Y 6/1
N8
5Y 6/1
N8
N7
Void
N8
5Y 6/1
N7
5Y 6/1
N8
5Y 6/1
N7
5Y 6/1
N7
5Y 6/1
N8
5Y 8/1
N8
IW
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
5Y 6/1
N8

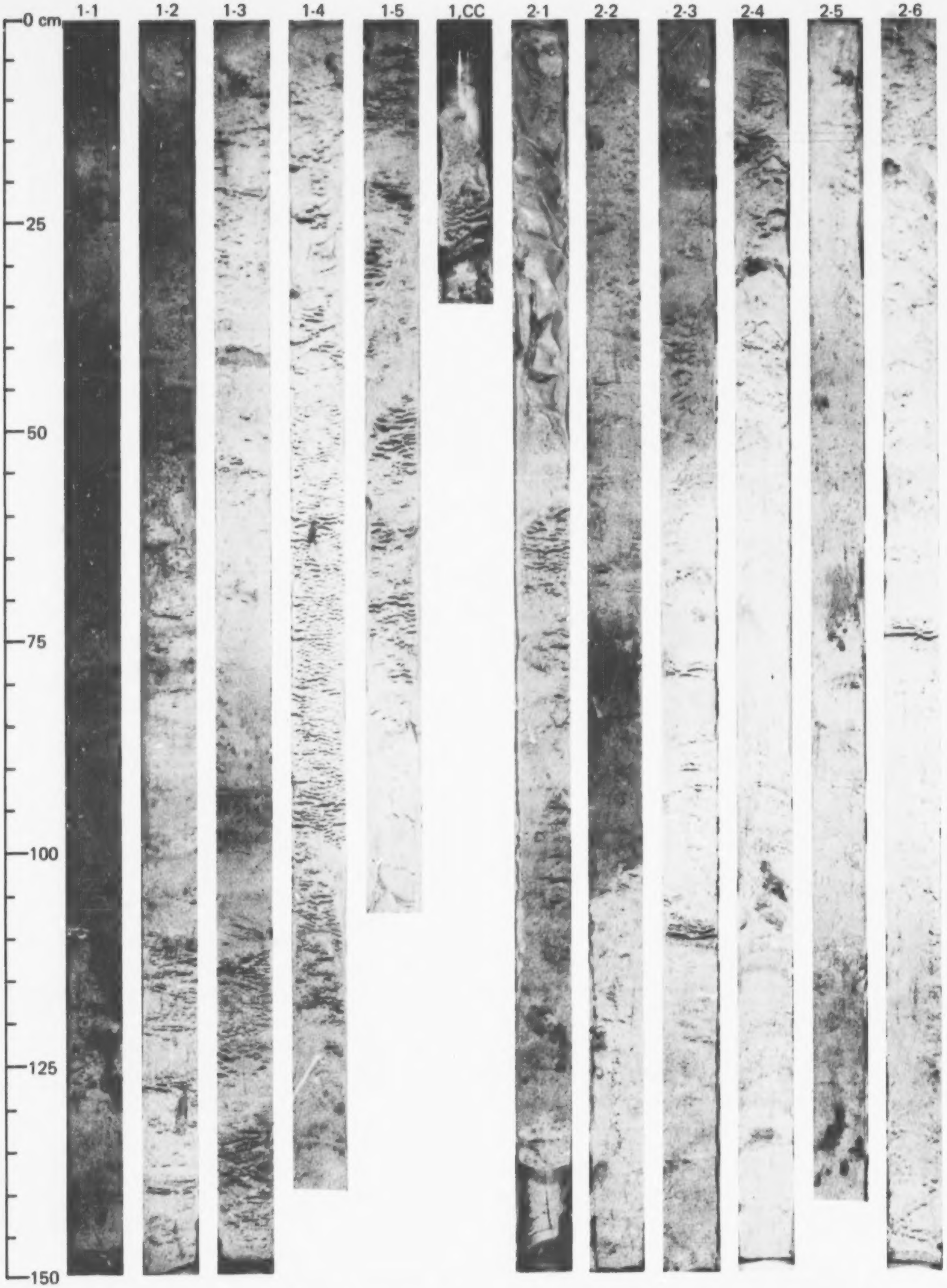
LITHOLOGIC DESCRIPTION

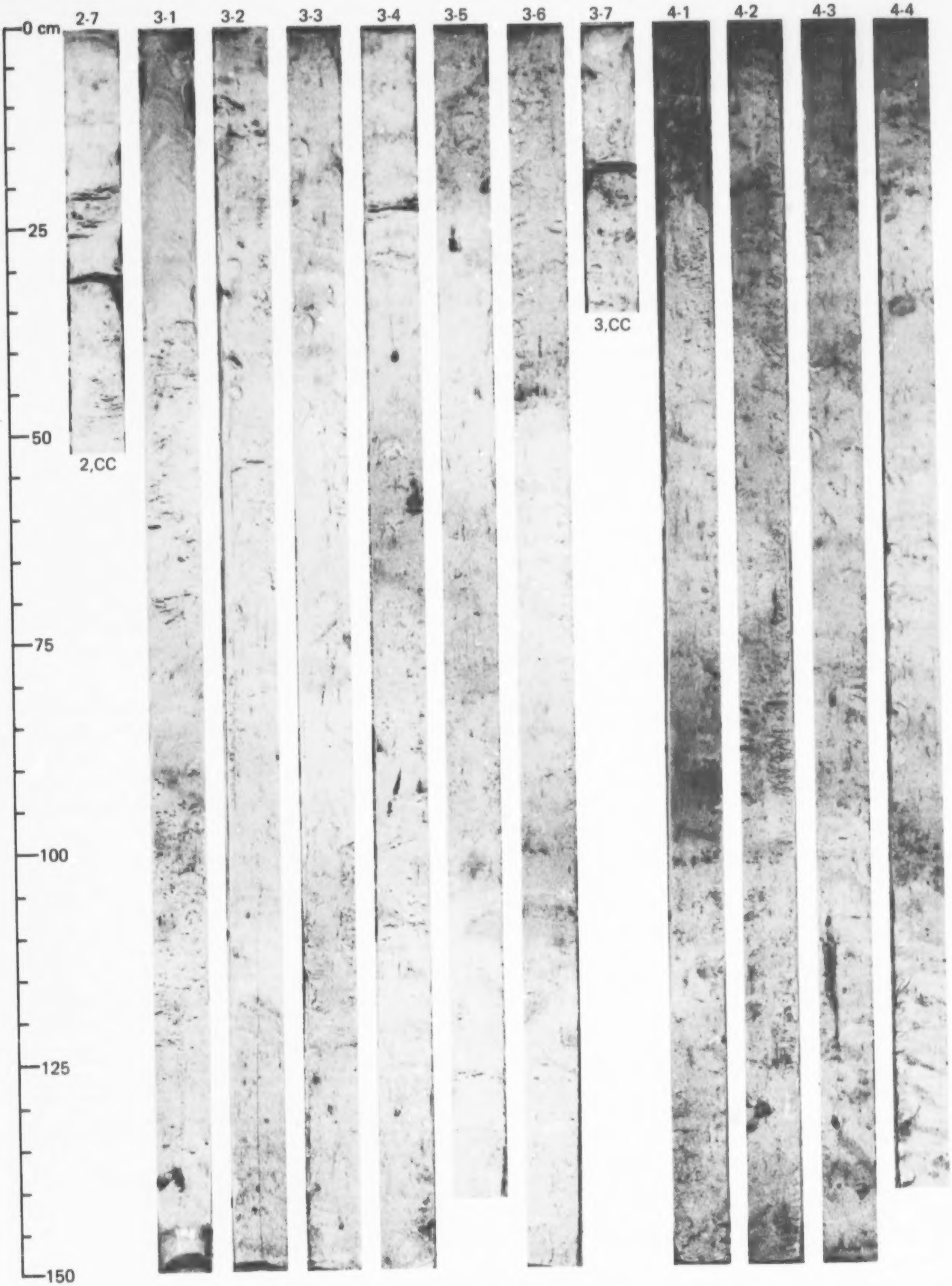
FORAMINIFER-BEARING NANNOFOSSIL OOZE, altering soft, very light gray (N8) and finer, light olive gray (5Y 6/1) dominant lithologies with fairly sharp contacts. Dark gray (N3) iron sulfide blebs and streaks occur periodically. Burrowing apparent at irregular intervals. Light olive gray (5Y 6/1) parts richer in forams.

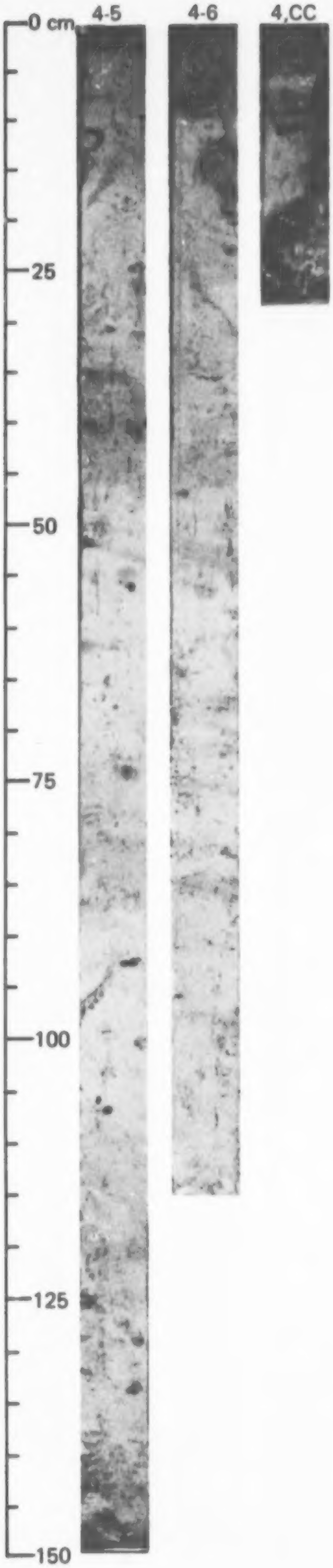
→ FORAMINIFER NANNOFOSSIL OOZE

SMEAR SLIDE SUMMARY

	1, 57	1, 91	2, 83	3, 91	4, 37	4, 99	5, 65
	D	D	D	D	D	D	D
Composition							
Quartz	–	–	–	–	–	–	T
Heavy minerals	T	T	T	T	T	T	T
Volcanic glass	–	–	R	–	–	–	–
Pyrite	–	R	T	–	R	R	T
Foraminifers	C	A	A	A	A	A	A
Calc. nannofossils	D	A	A	A	A	A	A
Sponge spicules	–	–	–	R	–	–	T


1-1
1-2
1-3
1-4
1-5
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
0 cm
25
50
75
100
125
150


2-7
3-1
3-2
3-3
3-4
3-5
3-6
3-7
4-1
4-2
4-3
4-4
0 cm
25
50
75
100
125
150
2,CC
3,CC



0 cm
4-5
4-6
4,CC
25
50
75
100
125
150

6. SITE 590: LORD HOWE RISE, 31°S[1]

Shipboard Scientific Party[2]

HOLE 590

Date occupied: 15 December 1982

Date departed: 15 December 1982

Time on hole: 13 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 26.2

Number of cores: 3

Total length of cored section (m): 26.2

Total core recovered (m): 26.36

Core recovery (%): 100

Oldest sediment cored:
Depth sub-bottom (m): 26.2
Nature: Foraminifer-nannofossil ooze
Age: early Quaternary

Basement: Not reached

HOLE 590A

Date occupied: 15 December 1982

Date departed: 17 December 1982

Time on hole: 51 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 280.8

Number of cores: 27

Total length of cored section (m): 254.6

Total core recovered (m): 224.17

Core recovery (%): 88.1

Oldest sediment cored:
Depth sub-bottom (m): 280.8
Nature: Nannofossil ooze
Age: Middle late Miocene

Basement: Not reached

HOLE 590B

Date occupied: 17 December 1982

Date departed: 19 December 1982

Time on hole: 49 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 499.1

Number of cores: 53

Total length of cored section (m): 499.1

Total core recovered (m): 465.26

Core recovery (%): 93.2

Oldest sediment cored:
Depth sub-bottom (m): 499.1
Nature: Recrystallized nannofossil chalk
Age: Earliest Miocene

Basement: Not reached

Principal results: Site 590 consists of three holes: Hole 590, which was cored continuously with the hydraulic piston corer (HPC) to 26.2 m sub-bottom; Hole 590A, which was cored continuously with the HPC from 26.2–280.8 m sub-bottom; and Hole 590B, which was cored continuously with the HPC from 0–250.7 m sub-bottom and rotary drilled with the extended core barrel (XCB) from 250.7–499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. This represents the first successful use of the XCB and it proves to be a most useful new coring tool.

The section is made up of one lithostratigraphic unit, represented mostly by foraminifer-bearing nannofossil ooze or foraminifer-rich nannofossil ooze. The sequence is divided into three subunits based on changes in color and degree of diagenesis. The upper part of the sequence contains more foraminifer-rich intervals because of increased winnowing that began about 3 m.y. The sequence contains only traces of nonbiogenic components, but volcanic ash is quite persistent. Multiple light green laminae from ear-

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), School of Earth Sciences, Flinders University of South Australia, Bedford Park, South Australia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; Charles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, P.O. Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, Stony Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National d'Histoire Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Sciences Division, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 96720; James V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Sciences, Open University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United Kingdom; William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, Littleton, CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgang-Goethe Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic of Germany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Oceanography, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, College Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. Geological Survey, Denver Federal Center, Denver, CO 80225); Campbell S. Nelson, Department of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Christian Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 13288 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu University, Varanasi 221 005, India; Rüdiger Stein, Geologisch-Paläontologisches Institut, Universität Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petroleum and Organic Geochemistry (ICH-5), Kernforschungslage Jülich GmbH, P.O. Box 1913, 5170 Jülich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, Faculty of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

ly late Miocene to early Miocene are possibly altered volcanic ash layers. Biostratigraphic zonal sequences of transitional type are an important temperate component of the assemblages. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene. A paleomagnetic polarity stratigraphy has been identified down to the middle part of the Gilbert Chron (about 4.2 m.y.).

The Site 590 section provides a superb sequence of pristine foraminifers during the last 15 m.y. and of calcareous nannofossils during the last 10 m.y. The Pliocene/Quaternary and Miocene/Pliocene boundaries are well represented and exhibit clear, gradual, evolutionary sequences within some lineages. The Miocene/Pliocene boundary sequence is missing from the nearby Site 206 sequence.

Remarkably high calcareous biogenic sedimentation rates occur during most of the Pliocene and the middle and late Miocene. Rates (uncorrected for sediment porosity) are as follows for Hole 590B: early Miocene (base NN2-top NN3) 14.4 m/m.y.; middle Miocene (to top NN7) 29.4 m/m.y.; middle late Miocene-early Pliocene (to top NN13) 29.1 m/m.y.; early late Pliocene (to top N18) 52.4 m/m.y.; Quaternary, 17.2 m/m.y.

The seismic profile in the area shows no clear ponding of sediments in much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, which are spectacularly high in the Pliocene, are due to biogenic productivity associated with the Tasman Front.

BACKGROUND AND OBJECTIVES

Site 590 lies to the east of the crest of Lord Howe Rise (Fig. 1). This site was selected as one of several that make up a north-south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites which form a depth traverse for the study of changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m). The seismic reflection profile (Fig. 2) indicates the presence of a relatively thick sequence of pelagic sediments near the site.

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. Site 206 is situated at 32°00′S; 165.27′E. Although Site 206 is a valuable Neogene rotary-cored section, it suffers from a large number of coring gaps, especially in the early Miocene, and contains an unconformity over the Miocene/Pliocene boundary which eliminates important biostratigraphic information. Furthermore, because of the depth of this site (3196 m, below the foraminiferal lysocline), the planktonic foraminiferal assemblage has been altered by dissolution.

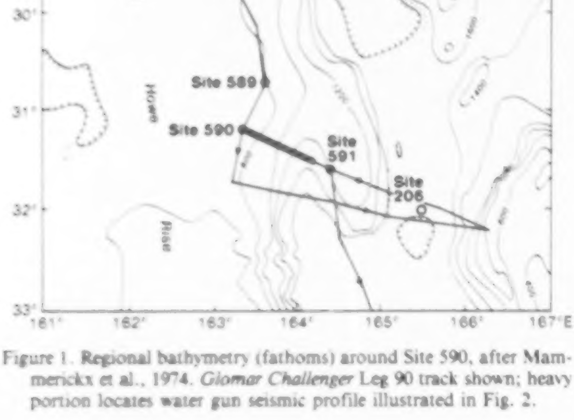

Figure 1. Regional bathymetry (fathoms) around Site 590, after Mammerickx et al., 1974. *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

There are three main reasons why Site 590 was chosen:

1. It is strategically located in waters transitional between the warm subtropical and temperate water masses and is of potential importance in correlating stratigraphic sequences of those areas.
2. It lies at relatively shallow depths near the crest of Lord Howe Rise; and
3. Seismic profile data (Fig. 2) indicate that the area is a quiet pelagic environment and should provide a complete or nearly complete Neogene sequence of carbonate oozes.

Because Site 590 is located in such shallow water, and almost certainly has been located above the foraminiferal lysocline during the entire Neogene, it was expected that foraminiferal and calcareous nannofossil assemblages of this age would be well preserved and would provide an excellent paleoceanographic and paleoclimatic record. An important water mass boundary—the Tropical Convergence—separates the transitional from the warm subtropical water masses. The boundary represents the zone between the eastward flowing East Australian Current and the Trade Wind drift. Its position corresponds fairly closely with the southern limit of the southeast Trade Wind belt, where wind directions change from southwest to southeast, thereby creating convergent flow. The system is quite weak and disappears in summer when the Trade Wind drift turns south. That the tropical convergence is an important surface water mass barrier is suggested by the biogeographic and paleobiogeographic patterns of the planktonic foraminifers (Srinivasan and Kennett, 1981). Faunas at Site 206 have a much more important temperate element than those at Site 208. Paleoreconstructions of this region (Sclater et al., in press) show that Site 590 was about 5–10° of latitude further south in the early Neogene than it is now. This would have placed it well within the zone of westerlies during the early Neogene, with truly temperate planktonic assemblages.

The drilling plan at Site 590 was to core two sites using the hydraulic piston corer to refusal and then to rotary core continuously down to the upper Oligocene.

OPERATIONS

Sites 589 to 590

Following the shipboard computer failure at Site 589, southward transit to an alternate site (1) provided extra time to discover and repair the problem with the positioning computer, (2) if that proved impossible within 8 hr., would have placed the ship closer to New Zealand, where repairs could be made with expert assistance, and (3) would provide time to take seismic profiles in areas of potential new sites (alternates to SW-4 and SW-6) for

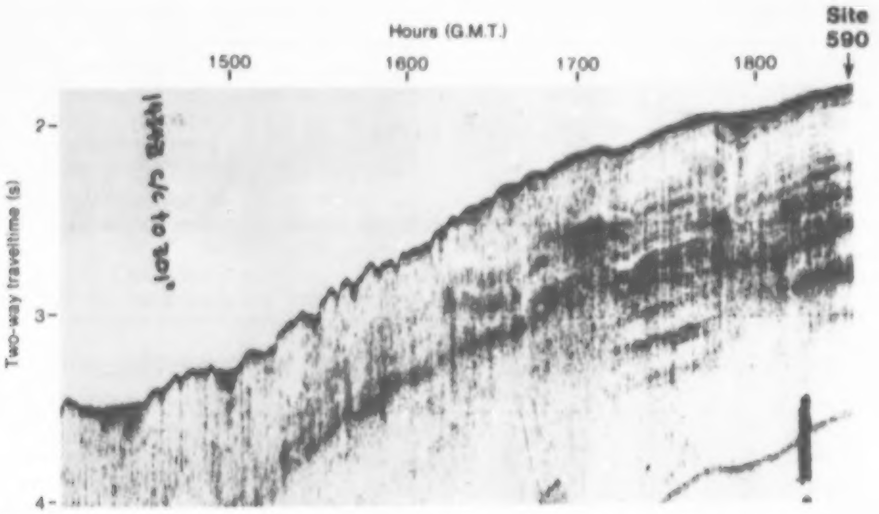

Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 590; bandpass filter 40–160 Hz.

the same scientific objectives. Further time was also necessary to obtain approval to drill the new sites from the JOIDES Safety Panel.

After possible alternate sites had been surveyed, the problem with the computer had still not been identified, and the ship changed course for Auckland, New Zealand, at 2003 hr., 13 December.

After we had steamed toward Auckland for more than 17 hr., the computer problem was located and repaired, and the vessel immediately returned to the newly chosen Site SW-4, following a track close to the one profiled upon departure from that site. The beacon (13.5 kHz) was dropped at 0533 hr., 15 December 1982. The total distance traveled since departure from Site 589 was 413 mi., at an average speed of 10.09 knots.

Site 590 (new SW-4): Central Lord Howe Rise

Site 590 was located on the Lord Howe Rise, roughly south of and at a water depth equivalent to that of the original SW-4 site specified in the scientific prospectus. Seismic profiling (Fig. 2) showed a sub-bottom character similar to the original SW-4.

Authorization to piston core the new site was received via radio before reaching SW-4, so there was no delay in operations. Once again a dual-purpose bottom-hole assembly (BHA) was lowered to enable piston coring followed by XCB rotary coring. The bit was lowered to 1305 m and a mudline variable-length (VL) HPC core containing 7 m of sediment was taken at 1210 hr., 15 December, after an initial mudline core had been discarded when the core liner shattered.

Three 9.5-m VLHPC cores were taken routinely (Table 1). The fourth attempt was unsuccessful when the coring tool was accidently allowed to fall several feet, so that it hit the lifting clamp violently. This ultimately caused a dislocation of the lower section of the piston corer, which was lost through the bit. Unfortunately, the Von Herzen heat-flow package was attached to the lost tool. Because only one Von Herzen heat-flow electronic unit had been available to Leg 90, its scientific value was high; therefore an unsuccessful effort was made to fish for the lost barrel, which was believed to be stuck in the mud only about 3 ft. below the bit. About 2½ hr. were spent making up a special fishing spear and deploying it through the bit. Hole 590 was terminated because of the obstruction.

Hole 590A

The bit was pulled to the mudline and washed back to the point where Core 590-4 was to have been taken. Hole 590A was spudded at 1810 hr., 15 December, and routine piston coring operations were resumed.

At Core 590A-13, the sand line parted at the rope socket on top of the sinker bar assembly. The sinker bars and VLHPC were successfully fished on the first attempt, so little time was lost.

As at the previous sites, full stroke of the piston corer was achieved continuously, generally with only two shear pins. At a depth of 275.8 m BSF, overpulls of 45,000 lb. made it necessary to wash the bit over the protruding corer in order to retrieve the tool. A 5-m VLHPC was then deployed, but it, too, had to be washed over for release. Therefore, piston coring was deemed to be too dangerous to be continued, despite the fact that high-quality full-stroke cores were still being taken.

Hole 590B

Authorization to rotary core this new site had not yet been received, so the repeat piston core sequence was begun by pulling to the mudline and re-establishing water depth with a mudline core after the vessel had been offset 100 ft. The first core was shot with the bit at 1301 m, in order to overlap the piston cores with those from Hole 590A. Hole 590B was officially spudded at 2110 hr., 16 December.

Twenty-seven 9.5-m VLHPC cores were taken without any difficulties in calcareous sediment grading from soupy ooze to firm chalk. Piston coring was terminated at 250.7 m BSF when the familiar pattern of increasing overpull symptoms repeated itself.

Table 1. Coring summary, Site 590.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 590							
1	15	1235	1307.6-1314.6	0.0-7.0	7.0	6.99	100
2	15	1305	1314.6-1324.2	7.0-16.6	9.6	9.70	100+
3	15	1408	1324.2-1333.8	16.6-26.2	9.6	9.67	100+
		Core barrel broken			26.20	26.36	100
Hole 590A							
1	15	1430	1333.8-1343.4	26.2-35.8	9.6	9.41	98
2	15	2012	1343.4-1353.0	35.8-45.4	9.6	9.39	98
3	15	2115	1353.0-1362.6	45.4-55.0	9.6	8.53	89
4	15	2200	1362.6-1372.2	55.0-64.6	9.6	8.76	91
5	15	2255	1372.2-1381.8	64.6-74.2	9.6	9.22	96
6	15	2343	1381.8-1391.4	74.2-83.8	9.6	9.42	98
7	16	0015	1391.4-1401.0	83.8-93.4	9.6	9.02	94
8	16	0100	1401.0-1410.6	93.4-103.0	9.6	9.50	99
9	16	0150	1410.6-1420.2	103.0-112.6	9.6	0.0	0
10	16	0245	1420.2-1429.8	112.6-122.2	9.6	8.86	92
11	16	0330	1429.8-1439.4	122.2-131.8	9.6	9.71	100
12	16	0445	1439.4-1449.0	131.8-141.4	9.6	9.60	100
132	16	0630	1449.0-1458.6	141.4-151.0	9.6	8.26	86
14	16	0800	1458.6-1468.2	151.0-160.6	9.6	9.29	97
15	16	0850	1468.2-1477.8	160.6-170.2	9.6	9.50	99
16	16	0950	1477.8-1487.4	170.2-179.8	9.6	7.45	78
17	16	1015	1487.4-1497.0	179.8-189.4	9.6	7.85	82
18	16	1105	1497.0-1506.6	189.4-199.0	9.6	9.10	95
19	16	1200	1506.6-1516.2	199.0-208.6	9.6	8.26	86
20	16	1255	1516.2-1525.8	208.6-218.2	9.6	8.75	91
21	16	1345	1525.8-1535.4	218.2-227.8	9.6	9.74	100+
22	16	1420	1535.4-1545.0	227.8-237.4	9.6	2.42	25
23	16	1510	1545.0-1554.6	237.4-247.0	9.6	9.20	96
24	16	1600	1554.6-1564.2	247.0-256.6	9.6	9.71	100+
25	16	1710	1564.2-1573.8	256.6-266.2	9.6	9.11	100+
26	16	1820	1573.8-1583.4	266.2-275.8	9.6	8.91	93
27	16	1915	1583.4-1588.4	275.8-280.8	5.0	5.20	100+
					254.60	224.17	88.1
Hole 590B							
1	16	2135	1308.4-1310.6	0.0-2.2	2.2	2.10	95
2	16	2220	1310.6-1320.2	2.2-11.8	9.6	9.22	96
3	16	2300	1320.2-1329.8	11.8-21.4	9.6	9.65	100+
4	16	2355	1329.8-1339.4	21.4-31.0	9.6	9.58	99.7
5	17	0035	1339.4-1349.0	31.0-40.6	9.6	9.40	97.9
6	17	0100	1349.0-1358.6	40.6-50.2	9.6	9.60	100
7	17	0140	1358.6-1368.2	50.2-59.8	9.6	9.59	99.9
8	17	0300	1368.2-1377.8	59.8-69.4	9.6	9.24	96.2
9	17	0400	1377.8-1387.4	69.4-79.0	9.6	8.05	83.8
10	17	0445	1387.4-1397.0	79.0-88.6	9.6	8.87	92.4
11	17	0535	1397.0-1406.6	88.6-98.2	9.6	9.00	93.7
12	17	0620	1406.6-1416.2	98.2-107.8	9.6	8.52	88.7
13	17	0700	1416.2-1425.8	107.8-117.4	9.6	9.29	96.7
14	17	0740	1425.8-1435.4	117.4-127.0	9.6	9.74	100+
15	17	0830	1435.4-1445.0	127.0-136.6	9.6	9.06	94.4
16	17	0920	1445.0-1454.6	136.6-146.2	9.6	8.76	91.2
17	17	1005	1454.6-1464.2	146.2-155.8	9.6	9.49	98.8
18	17	1045	1464.2-1473.8	155.8-165.4	9.6	8.03	83.6
19	17	1120	1473.8-1483.4	165.4-175.0	9.6	8.33	86.7
20	17	1210	1483.4-1493.0	175.0-184.6	9.6	9.38	98
21	17	1315	1493.0-1502.6	184.6-194.2	9.6	8.44	88
22	17	1410	1502.6-1512.2	194.2-203.8	9.6	6.07	63.2
23	17	1510	1512.2-1521.8	203.8-213.4	9.6	9.47	99
24	17	1550	1521.8-1531.4	213.4-223.0	9.6	8.66	90
25	17	1645	1531.4-1541.0	223.0-232.6	9.6	8.51	89
26	17	1750	1541.0-1550.6	232.6-242.2	9.6	9.73	100+
27	17	1855	1550.6-1559.1	242.2-250.7	8.5	8.49	99
28	17	1950	1559.1-1567.5	250.7-259.1	8.4	9.28	100+
29	17	2055	1567.5-1577.1	259.1-268.7	9.6	8.88	92
30	17	2200	1577.1-1586.7	268.7-278.3	9.6	8.28	86
31	17	2310	1586.7-1596.3	278.3-287.9	9.6	7.84	81.6
32	17	2345	1596.3-1605.9	287.9-297.5	9.6	9.25	96.3
33	18	0043	1605.9-1615.5	297.5-307.1	9.6	9.63	100+
34	18	0200	1615.5-1625.1	307.1-316.7	9.6	8.43	87.8
35	18	0250	1625.1-1634.7	316.7-326.3	9.6	7.60	79.1
36	18	0340	1634.7-1644.3	326.3-335.9	9.6	9.50	98.9
37	18	0432	1644.3-1653.9	335.9-345.5	9.6	9.64	100+
38	18	0520	1653.9-1663.5	345.5-355.1	9.6	9.65	100+
39	18	0610	1663.5-1673.1	355.1-364.7	9.6	9.73	100+
40	18	0700	1673.1-1682.7	364.7-374.3	9.6	9.71	100+
41	18	0745	1682.7-1692.3	374.3-383.9	9.6	9.76	100+
42	18	0830	1692.3-1701.9	383.9-393.5	9.6	9.61	100+
43	18	0915	1701.9-1711.5	393.5-403.1	9.6	7.48	77.9
44	18	1005	1711.5-1721.1	403.1-412.7	9.6	9.65	100+
45	18	1100	1721.1-1730.7	412.7-422.3	9.6	7.72	80.4
46	18	1200	1730.7-1740.3	422.3-431.9	9.6	9.78	100+
47	18	1255	1740.3-1749.9	431.9-441.5	9.6	9.68	100+
48	18	1355	1749.9-1759.5	441.5-451.1	9.6	9.68	100+
49	18	1450	1759.5-1769.1	451.1-460.7	9.6	7.19	75
50	18	1550	1769.1-1778.7	460.7-470.3	9.6	4.31	45
51	18	1650	1778.7-1788.3	470.3-479.9	9.6	9.42	98
52	18	1755	1788.3-1797.9	479.9-489.5	9.6	9.61	100+
53	18	1850	1797.9-1807.5	489.5-499.1	9.6	9.68	100+
					499.10	465.26	93.2

The XCB with its latest modifications was deployed. Excellent cores with high recovery rates were taken. Seven of the first nine cores were retrieved with the liner partially collapsed, but the collapse was always limited to the top 3 ft. or less. This problem was soon eliminated. Twenty-six cores were taken with the XCB to a depth of 499.1 m BSF, where the hole was terminated when the quality of the recovered microfossils deteriorated to the point that useful paleoceanographic work became impossible.

The pipe was tripped and the rig floor was secured for sea. The vessel departed for Site 591 at 2248 hr., 18 December 1982.

LITHOSTRATIGRAPHY

The sequence recovered at Site 590 is dominantly composed of calcareous biogenic sediments which constitute a single lithostratigraphic unit with three subunits (Table 2; Fig. 3). The principal biogenic components are calcareous nannofossils and foraminifers (Fig. 4). The sediments range from an occasional nannofossil–foraminifer ooze through common foraminifer-bearing nannofossil ooze (or chalk) to fairly pure nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, having greatest abundance (1 to 5%) in Cores 590B-32 to 590B-35. The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasionally sponge spicules.

Nonbiogenic components comprise an extremely small proportion of the sediment. Occasional quartz and feldspar grains are present. Trace quantities of clear volcanic glass occur throughout the sequence, and distinct concentrations of volcanic ash were observed in Cores 590A-6, 590B-38, and 590B-51. Zeolites(?) and palagonite occur in Cores 590B-48 to 590B-53. Numerous pale green laminae occur and are most prevalent in Cores 590B-33 to 590B-53. These are possibly related to the presence of increased quantities of volcanic ash. Authigenic iron sulfide occurs within burrows and foraminifer tests, and as finely dispersed medium gray streaks and halos throughout the sequence. Grayish yellow concretions measuring up to 5 cm in diameter were found in Cores 590B-18, 590B-20, and 590B-23. These are composed predominantly of celestite with pyrite crystals occurring on the surface or as a central core.

The sediment becomes more indurated with depth. Sediments above 280 m sub-bottom are ooze that becomes progressively stiffer with depth. Sediments below

Table 2. Lithostratigraphy at Site 590.

Lithostratigraphic unit	Core	Sub-bottom depth (m)	General lithology	Age
IA	590-1 590B-1	0-40 cm 0-30 cm	Yellowish orange foraminifer-nannofossil ooze	late Quaternary
IB	590-1 to 590-3 590A-1 to 590A-27 590B-1 to 590B-30	0.4-26.2 26.2-280.8 0.4-278.3	Very light gray foraminifer-bearing nannofossil ooze to light olive gray foraminifer-nannofossil ooze.	late Miocene
IC	590B-31 to 590B-53	278.1-499.1	Light gray foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk	late Miocene to early Miocene

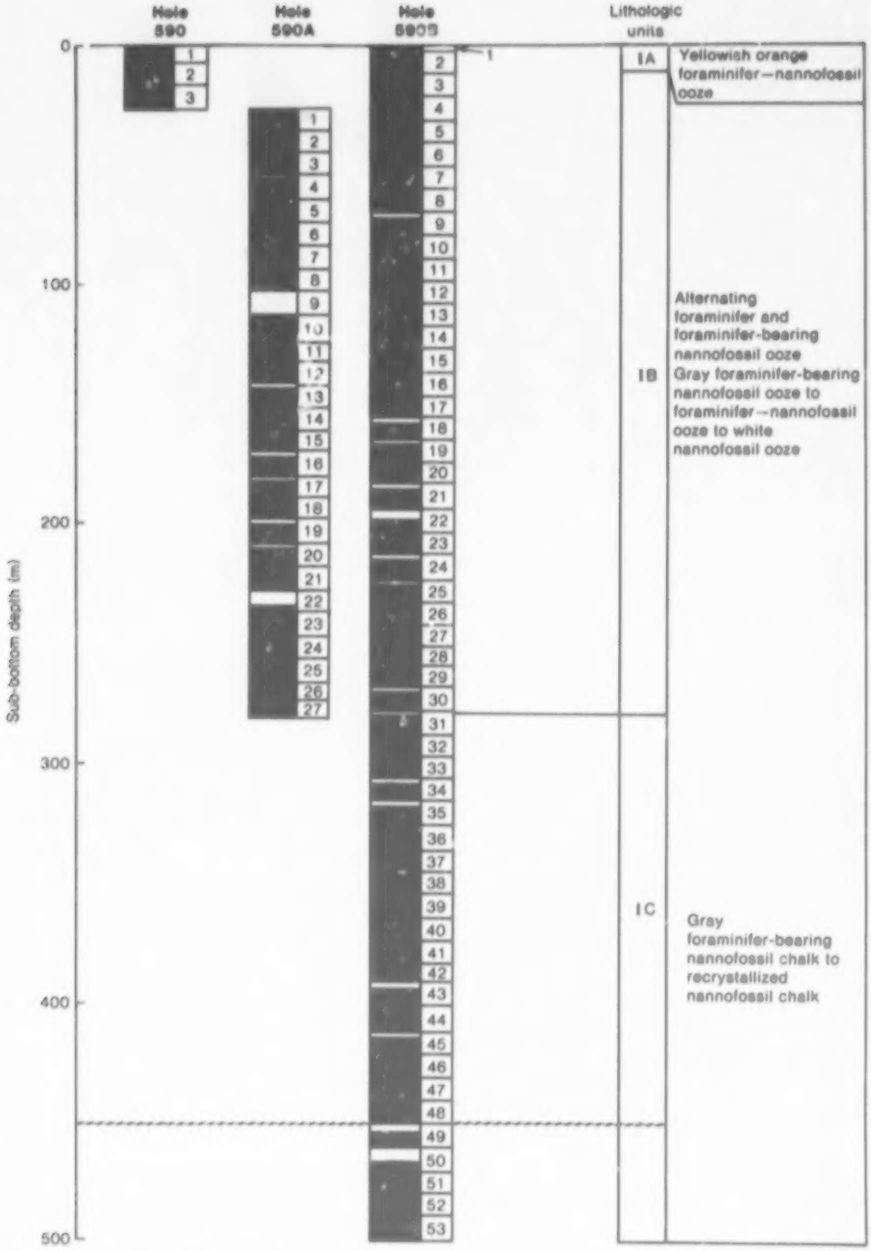
Hole 590
Hole 590A
Hole 590B
Lithologic units
0
100
200
300
400
500
Sub-bottom depth (m)
1
IA
Yellowish orange foraminifer—nannofossil ooze
IB
Alternating foraminifer and foraminifer-bearing nannofossil ooze
Gray foraminifer-bearing nannofossil ooze to foraminifer—nannofossil ooze to white nannofossil ooze
IC
Gray foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk

Figure 3. Lithology of Site 590. Recovery in black.

approximately 280 m sub-bottom are chalk with clear recrystallization in Cores 590B-51 to 590B-53.

Sedimentary structures have been created by chemical, physical, and biological effects. Bioturbation is slight in the upper part of the sequence (Cores 590-1 to 590-3, 590A-1 to 590A-16, and 590B-1 to 590B-19), increases to moderate downhole (Cores 590A-17 to 590A-28, and 590B-20 to 590B-31), and becomes intense in Cores 590B-32 to 590B-47. The lowest part of the sequence, Cores 590B-48 to 590B-53, exhibits moderate bioturbation. Various color bands are apparent against the very light gray (N8) to white background of the ooze or chalk. The zones richer in foraminifers tend to be darker gray to light olive gray. Many burrows are yellowish gray (5Y 8/1). Numerous examples of Zoophycos as well as occasional Planolites-like and Chondrites-like burrows are apparent. Several suites of fractures were observed cutting the sediment sequence, but it is not clear whether or not they represent drilling artifacts. One microfault in Core 590B-35 is definitely unrelated to drilling activity, however, because it has clearly been annealed and occurs within a biscuit of hard sediment.

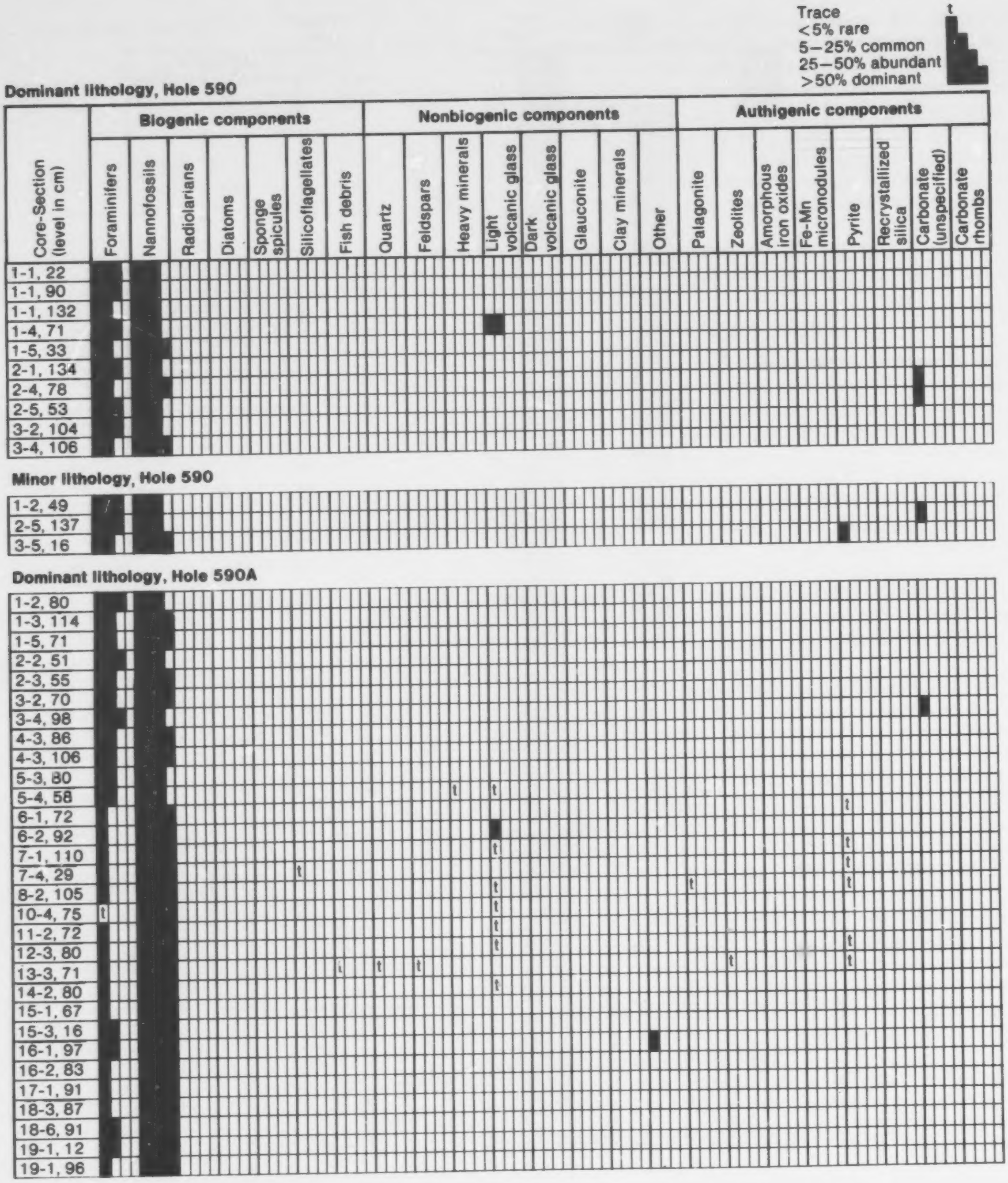

Figure 4. Smear slide summaries, Site 590.

The sequence at Site 590 is divided into three subunits, based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm sub-bottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer–nannofossil ooze. This subunit corresponds to the zone of oxidation and possible *current winnowing* activity and indicates that the uppermost sediments recovered are from near the sediment/water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing (5 to 10%) nannofossil ooze and layers of light olive gray foraminifer (20 to 50%) nannofossil ooze. The change in

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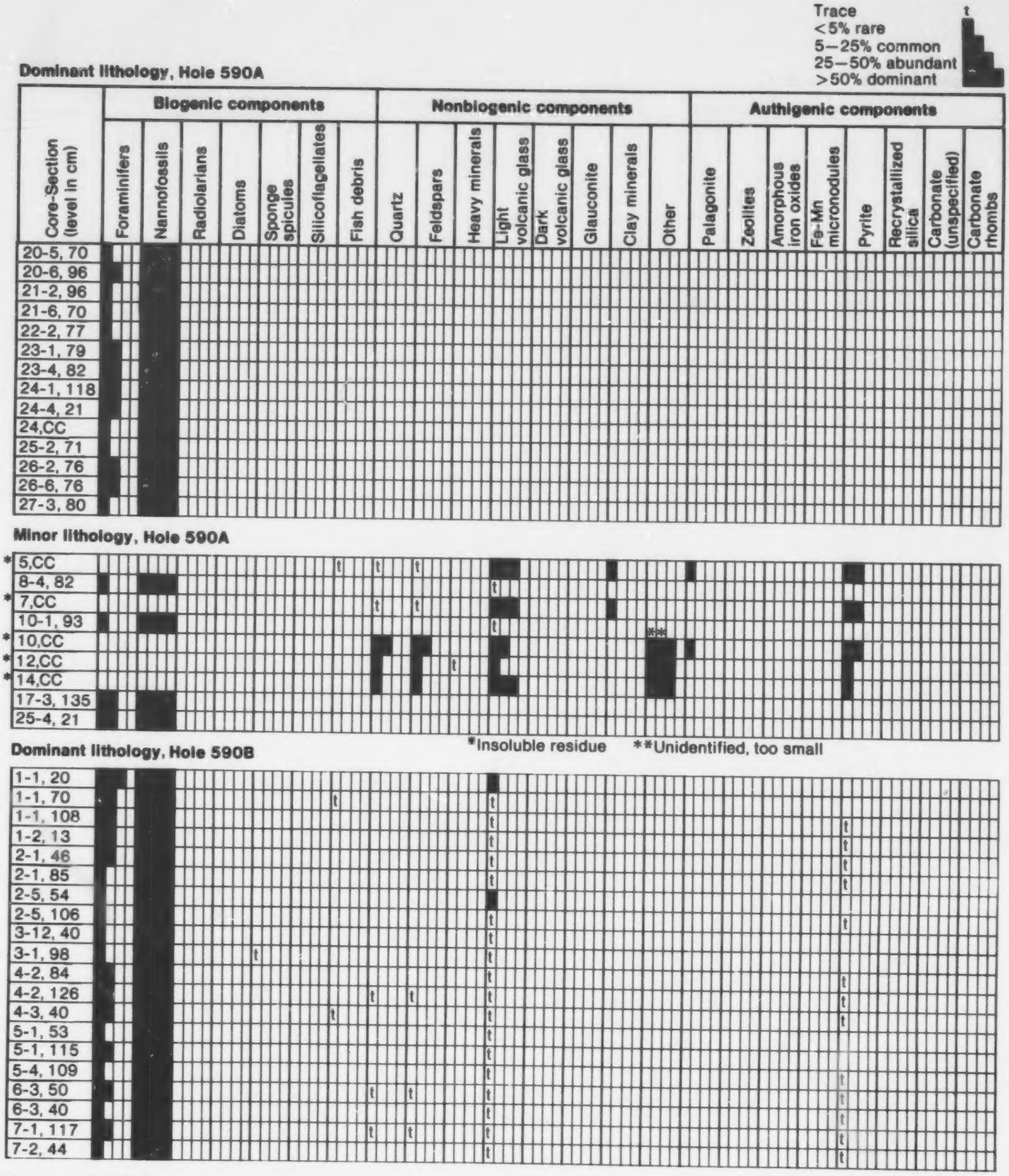

Figure 4. (Continued).

percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional zones of foraminifer-bearing (5 to 10%) nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions compared with the upper part of Subunit IB.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is

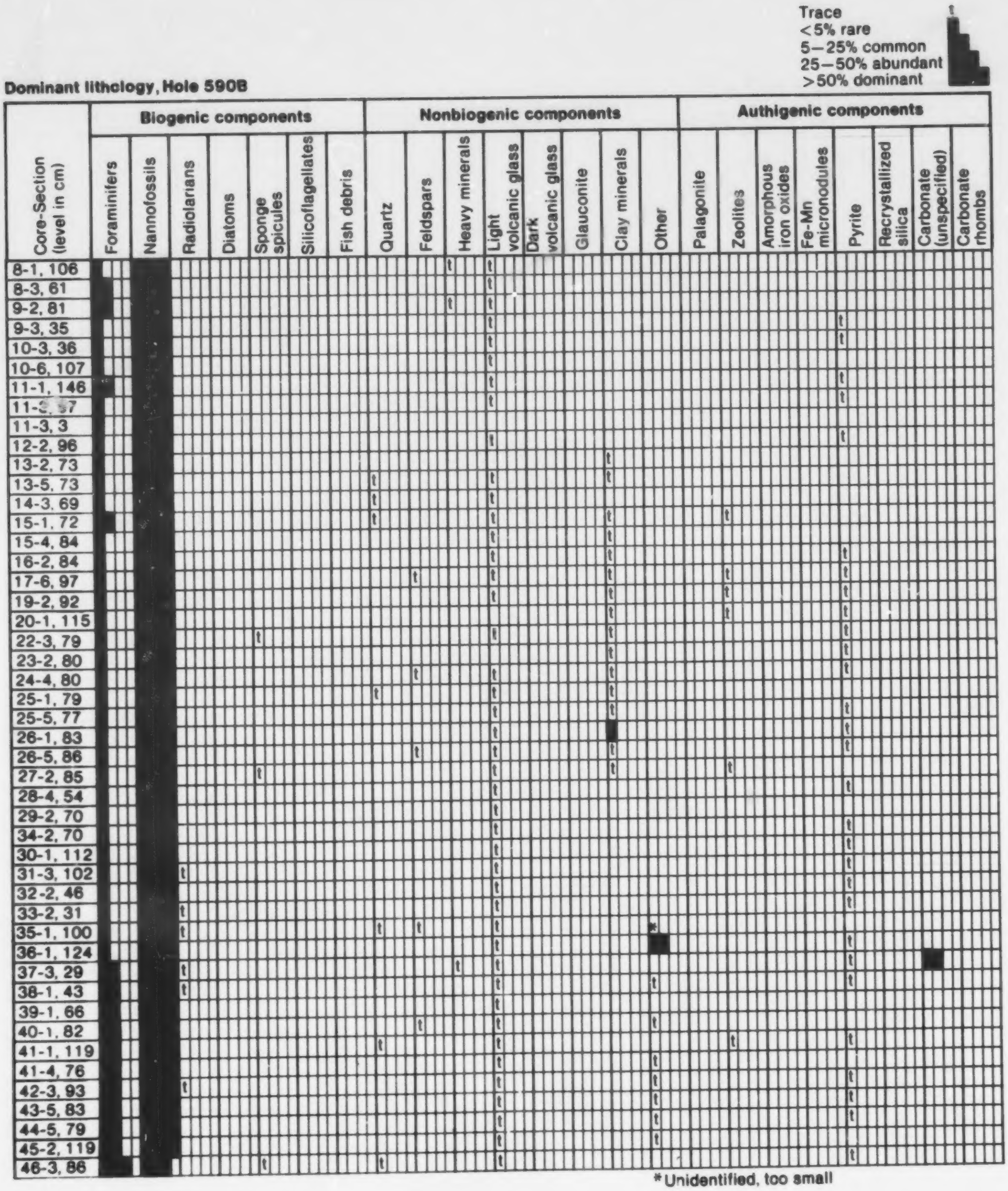

Figure 4. (Continued).

middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this part of the subunit. This subunit resembles the upper part of Subunit IB in consisting of alternating very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to foraminifer-bearing nannofossil chalk and foraminifer-nannofossil chalk, respectively. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450 to 499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk. This part of the subunit lacks the foraminifer-rich layers of the portion above and is

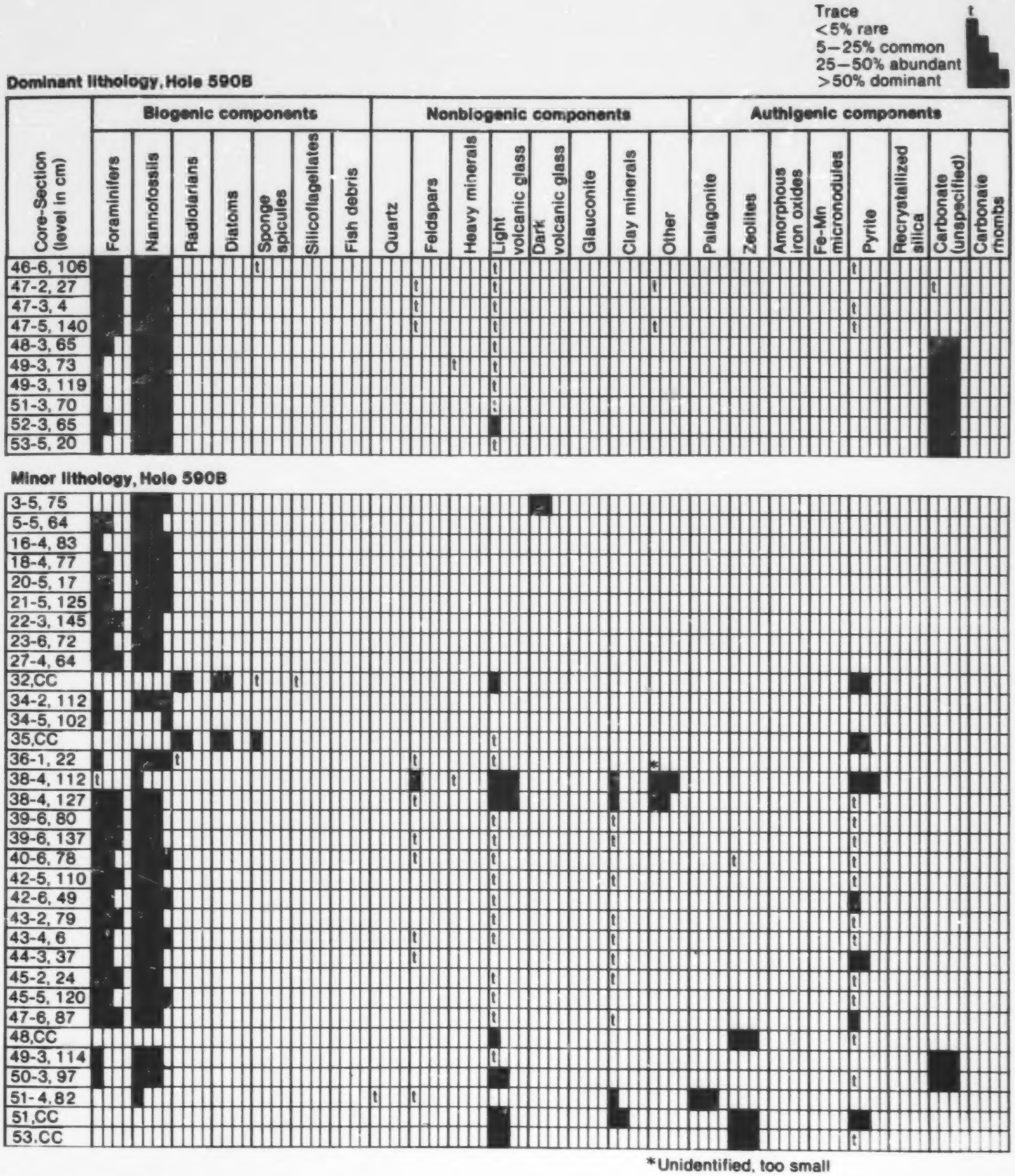

Figure 4. (Continued).

less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

PHYSICAL PROPERTIES

Wet-bulk density, porosity, and grain density were determined throughout the sediment column by using standard gravimetric methods (Boyce, 1976). The HPC cores were also continuously scanned with the GRAPE apparatus to measure wet-bulk density. Sonic velocity and shear strength were determined on each core section as well (see Introduction for specific techniques). A full discussion of the physical properties data for Site 590 is presented by Morin (this volume).

The GRAPE wet-bulk densities (points) for Hole 590B are plotted versus depth in Figure 5A. The results are averaged across each meter and these arithmetic mean values are plotted as the solid line (also relevant for Fig. 5B and 5C). The GRAPE porosities are directly calculated

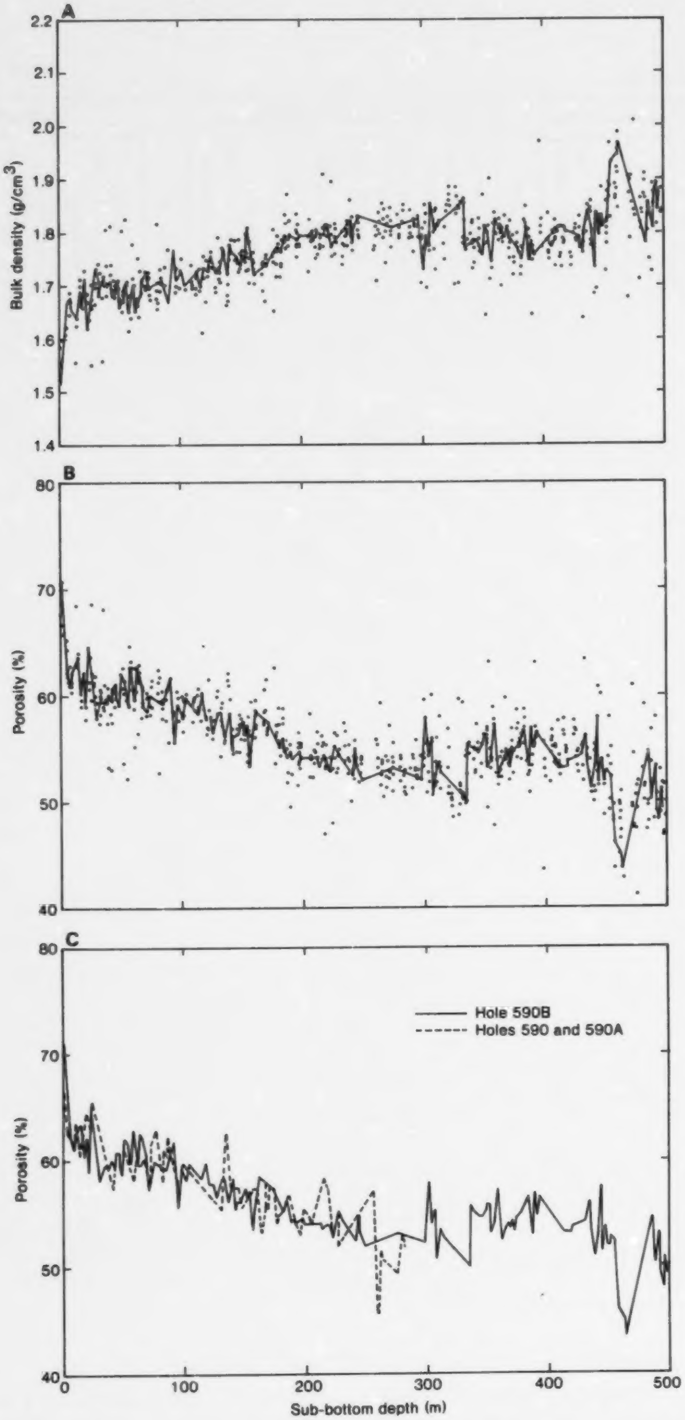

Figure 5. Physical properties, Site 590. A. GRAPE wet-bulk density versus sub-bottom depth for Hole 590B. B. GRAPE porosity versus sub-bottom depth for Hole 590B. C. GRAPE porosity versus sub-bottom depth for Holes 590, 590A, and 590B. D. Compressional velocity versus sub-bottom depth for Hole 590B. E. Porosity versus compressional velocity for Site 590. F. Shear strength versus sub-bottom depth for Hole 590B. G. Porosity versus shear strength for Hole 590B. H. Impedance versus depth for Hole 590B.

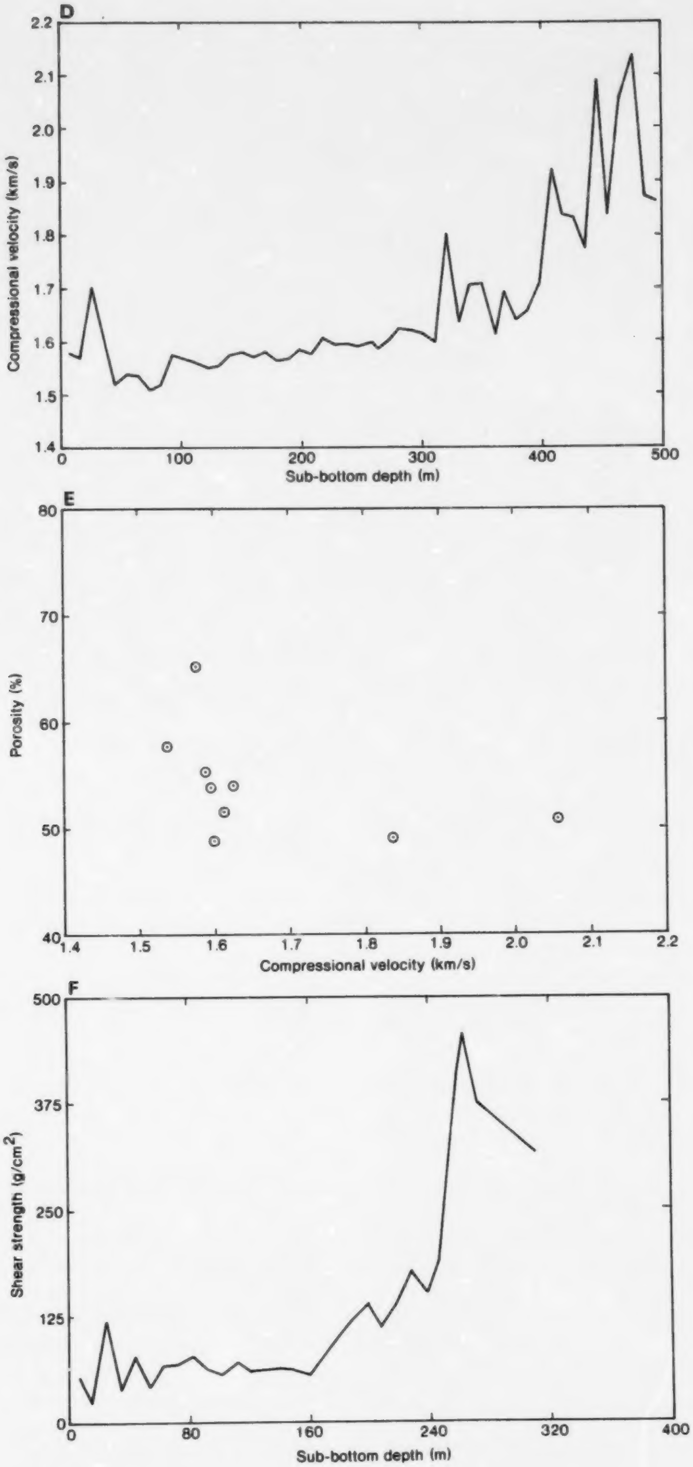

Figure 5. (Continued).

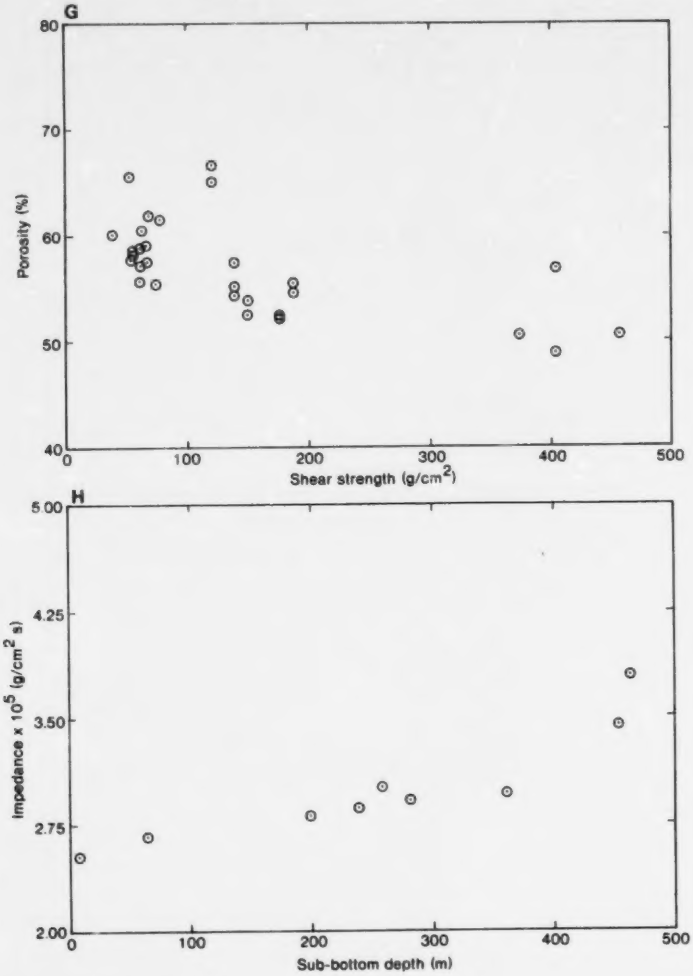

Figure 5. (Continued).

from the density results by assuming a grain density of 2.691 g/cm^3. Since the carbonate content of these sediments is very high ($CaCO_3$ grain density = 2.71 g/cm^3), this assumption provides a reasonable estimate of porosity versus depth (Fig. 5B). The porosity profile for Holes 590 and 590A is compared with that of Hole 590B in Figure 5C.

The results of the compressional velocity measurements performed on the split cores are illustrated in Figure 5D. A sharp increase in this property occurs at approximately 300 m, where the ooze-to-chalk transition is observed. When these data are correlated with the porosity profile, a plot of P-wave velocity versus porosity results (Fig. 5E). This graph illustrates how the acoustic velocity through the sediment at Site 590 increases dramatically as the porosity approaches 50%.

A similar presentation can be made with the shear strength data (Fig. 5F). The shear strength increases rapidly at 250 m. Below a depth of 300 m, the sediment becomes so lithified that its strength measurement is beyond the range of the Wykeham Farrance miniature vane shear device. Again, the sharp rise in the magnitude of this property occurs at the onset of chalk, where the sediment porosity approaches 50% (Fig. 5G).

An estimate of acoustic impedance as a function of depth can be derived by combining the P-wave velocity results with the GRAPE wet-bulk density profile (Fig. 5H). A rapid increase in impedance at a depth of approximately 450 m corresponds to the observed diagenetic recrystallization of the foraminifer-bearing nannofossil chalk.

SEISMIC STRATIGRAPHY

Figure 6 illustrates a portion of the shipboard water gun seismic profile collected during approach to Site 590. Five acoustic units have been identified (A to E), broadly equivalent to the regional acoustic units selected by Willcox et al., 1980. These are correlated in part with the lithology of the site (lithostratigraphic Subunits IA, IB, and IC).

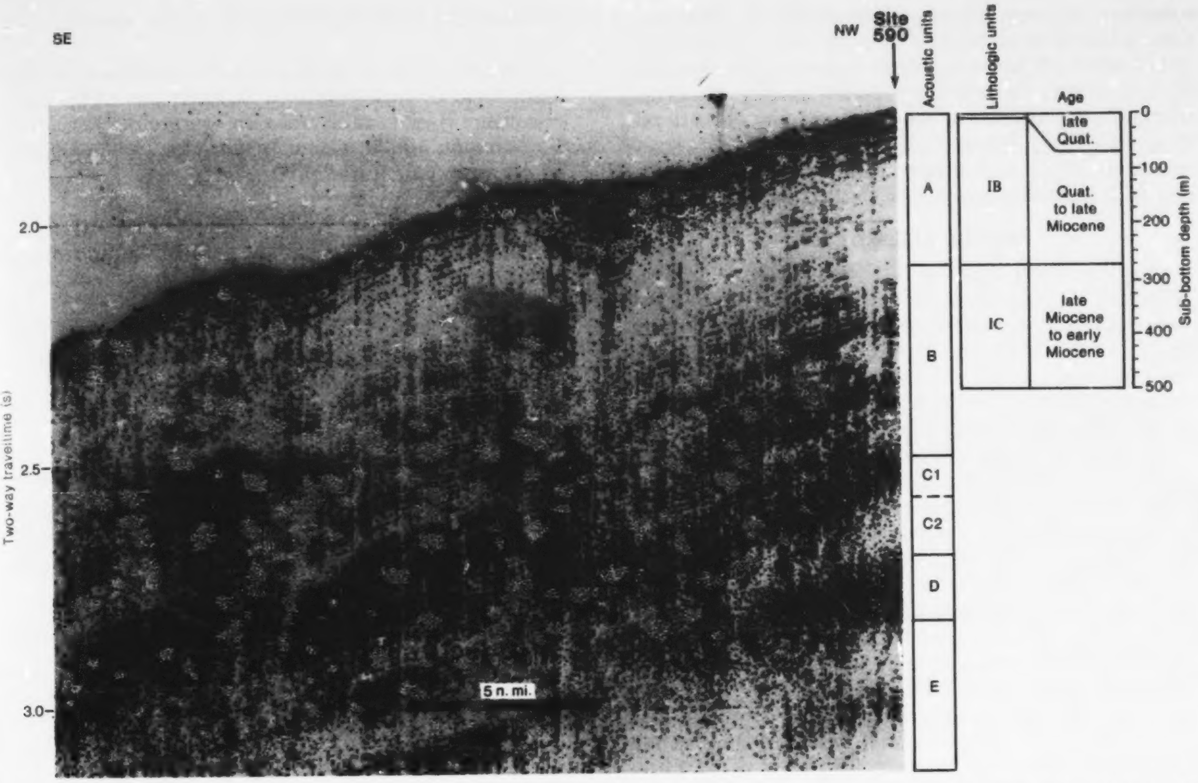

Figure 6. Comparison of acoustic Units A and B with lithologic Unit I Cored at Site 590; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1800 m/s.

Acoustic Unit A is a relatively transparent layer at recorded frequencies. Some relatively coherent reflectors are visible in its uppermost portion, below the reflected wave form. A small basin occurs 7 n. mi. southeast of Site 590, filled with significantly more reflective material. Further down the slope of Lord Howe Rise to the east-southeast (not shown in Fig. 6), additional filled channels or minor basins occur in a similar position with respect to the sediment surface.

Acoustic Unit B is not readily differentiated from A in the water gun record near Site 590. The upper boundary of B has been selected at the top of a slightly more reflective zone which contains layers of coherent reflectors.

Acoustic Unit C can be correlated regionally between drill sites on Lord Howe Rise with a high degree of confidence. It has a well-defined upper limit, and comprises a series of high-amplitude, relatively coherent reflectors (C1) underlain by a transparent zone (C2).[3] This unit has been subdivided in this summary into Subunits C1 and C2, in order to include the transparent zone (C2) which occurs below Site 590 and which occurs typically in grabens between acoustic units C and D. Generally, the highs between grabens are overlain by close juxtaposition of Units C and D, and the transparent Subunit C2 is missing.

Acoustic Unit D comprises a high-amplitude, relatively coherent set of reflectors with an appearance similar to that of Subunit C1.

Acoustic Unit E is a low-amplitude zone which, like C2, is largely confined to basinal areas (e.g., grabens). Its possible occurrence below Site 590 relates to what appears to be a relatively thick sedimentary sequence in this region of the Lord Howe Rise.

Site 590 was drilled to a total depth of 499.1 m, through acoustic Unit A and into B. The sequence has been assigned to three lithostratigraphic subunits. Subunit IA comprises late Quaternary foraminifer-nannofossil ooze, only 40 cm thick, and thus is not represented on Figure 6. Subunit IB comprises mixed foraminifer-bearing nannofossil ooze, foraminifer-nannofossil ooze, and nannofossil ooze, whereas Subunit IC is composed of foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk. Within the sequence, the downward gradation from ooze to chalk begins at a sub-bottom depth of about 275 m.

Comparison of these seismic and lithologic data suggests that the ooze/chalk boundary correlates with the boundary between acoustic Units A and B. This estimate is based on an interval velocity of 1.8 km/s, averaged from shipboard velocimeter measurements on cores. As described in the preceding section on Physical Properties, a rapid increase in acoustic impedance at a depth of approximately 450 m corresponds to diagenetic recrystallization of the foraminifer-bearing nannofossil chalk. The drilling terminated midway through acoustic Unit B.

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[3] Acoustic Unit C was not subdivided into C1 and C2 in the summary of Willcox et al., 1980, who may not have recognized Subunit C2 because of the lower frequencies employed during their seismic profiling. However, an effort has been made in this report to adhere to the original units chosen by Willcox et al.; accordingly, the transparent zone has been designated as a subunit.

BIOSTRATIGRAPHY

The three holes drilled at Site 590 provide a complete calcareous sequence from the early Miocene through Recent, except for an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorotalia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. This gap is not noted in the calcareous nannoplankton zonation, but may be within the *Sphenolithus heteromorphus* Zone (NN5, earliest middle Miocene). The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 was not observed at this site.

Preservation of calcareous nannoplankton is good in the upper part of the sequence and moderate to poor in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the lower Miocene unconformity and very poor below. The benthic foraminifers are well preserved throughout much of the sequence; however, below the upper Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers, perhaps as a result of diagenesis. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

For correlations between different fossil groups see Figure 7.

Planktonic Foraminifers

Zones

The planktonic foraminiferal zones recognized at Site 590 are shown in Figure 7. The zonal boundary marker species are noted in parentheses in the faunal descriptions that follow.

An unconformity exists between Samples 590B-48,CC and 590B-49,CC and the *Orbulina suturalis* Zone and *Praeorbulina glomerosa curva* Zone appear to be missing.

Faunas

***Globorotalia truncatulinoides* Zone (L.A. *Globorotalia tosaensis*)**

The zone fossil is in abundance and exists with *Globorotalia menardii, G. tumida, G. inflata*, and *Pulleniatina obliquiloculata*.

***Globorotalia truncatulinoides–G. tosaensis* Zone (I.A. *G. truncatulinoides*)**

The two zone fossils coexisted together with most species which survived into the *G. truncatulinoides* Zone.

***Globorotalia tosaensis* Zone (I.A. *G. tosaensis*)**

The zone fossil is abundant, with evidence of its evolution from *G. crassaformis* in the lower part of the zone; other important taxa include *Globigerinoides fistulosus, Globorotalia inflata, G. multicamerata, Dentoglobigerina altispira*, and *P. obliquiloculata*.

***Globorotalia inflata* Zone (I.A. *G. inflata*)**

The zone fossil is abundant at this site and occurs with *G. menardii, G. tumida*, and *P. obliquiloculata*.

***Globorotalia crassaformis* Zone (I.A. *G. crassaformis*)**

The zone fossil is abundant in the middle and upper part of the zone but is rarer in the lower part; important markers include *G. margaritae, G. puncticulata*, and *P. primalis*.

***Globorotalia puncticulata* Zone (I.A. G. puncticulata)**

The lower boundary was marked by the evolutionary appearance of the zone fossil with a transition form *G. sphericomiozea;* other important species within the zone include *G. miotumida* and *P. primalis*.

***Globorotalia conomiozea* Zone (I.A. *G. conomiozea*)**

The zone fossil is common within the zone with its typical morphology; thus it differs from Site 588; *G. conomiozea* and *G. margaritae* overlap in the uppermost part of the zone in 590A-18,CC.

***Globigerina nepenthes* Zone (L.A. *Neogloboquadrina continuosa*)**

The upper boundary is well established at this site with the probable evolutionary appearance of *Globorotalia conomiozea;* the lower boundary, based on the extinction of *N. continuosa*, is less securely established because of the scarcity of this species.

***Neogloboquadrina continuosa* Zone (L.A. *G. mayeri*)**

The zonal boundaries are marked by the extinction of the zone fossil at the top and *G. mayeri* at the base; within the zone there is little faunal change.

***Globorotalia mayeri* Zone (L.A. *Fohsella* group)**

The zone fossil was common within the zone; the lower boundary, marked by the extinction of the *Fohsella* lineage, may be stratigraphically low at this site because the keeled members of the *G. fohsi* lineage are absent.

***Globorotalia fohsi* s.l. Zone (I.A. *G. peripheroacuta*)**

The zone fossils, *G. peripheroacuta* and *G. fohsi* s.l., are rare within the zone, and the lower part of the zone may be missing.

***Globorotalia miozea* Zone (L.A. *Catapsydrax dissimilis*)**

Assemblages are poorly preserved within this zone, and identifications were difficult; nevertheless, the absence of *Orbulina* and *Praeorbulina* and the presence of the early Miocene *G. zealandica* confirmed the *G. miozea* Zone.

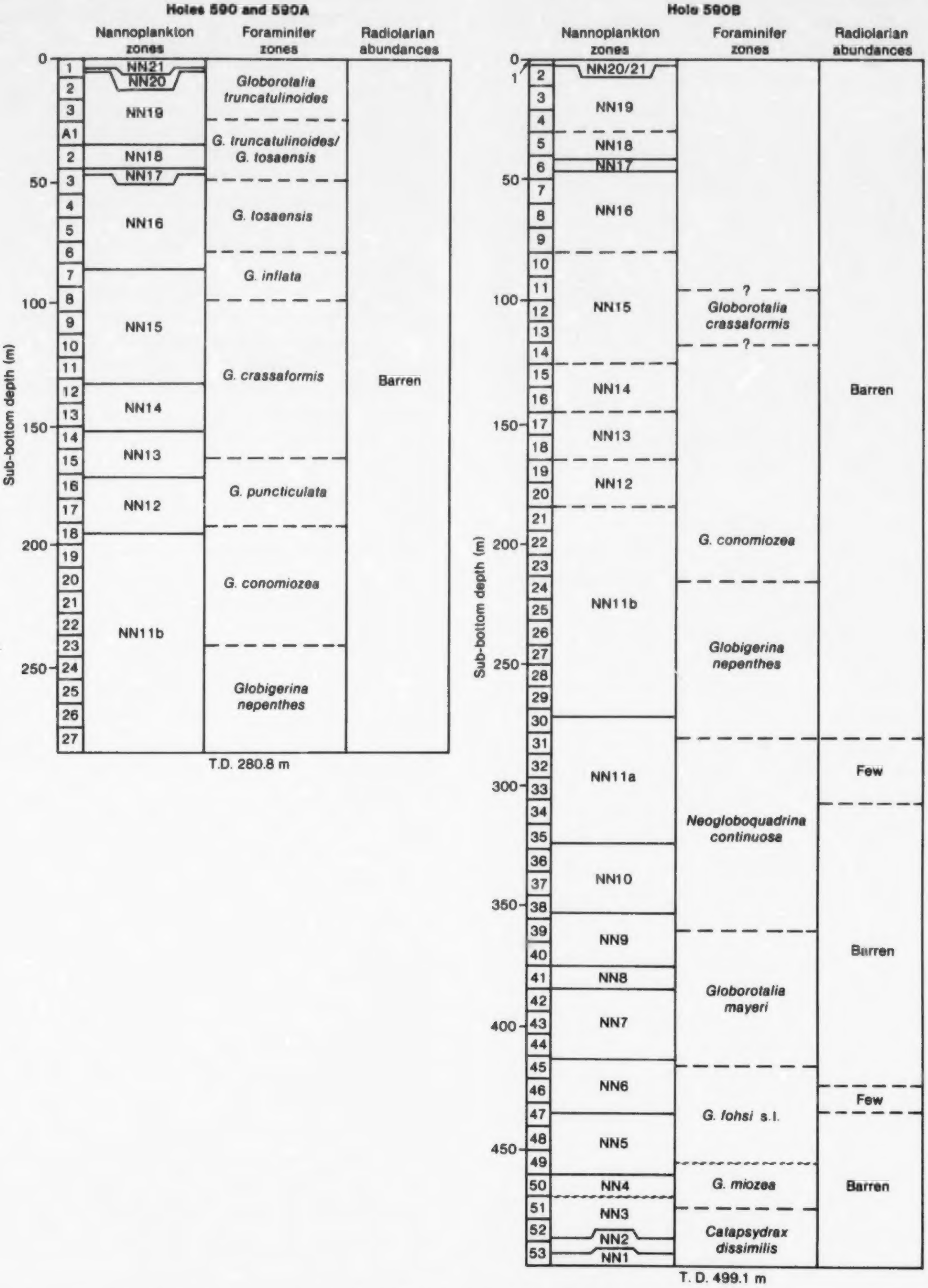


Figure 7. Correlation among calcareous nannoplankton, foraminifer, and radiolarian zones at Site 590.

Catapsydrax dissimilis Zone

There was very poor preservation of the fauna; the presence of the zonal fossil and the absence of *G. kugleri* confirmed the zonal designation.

Paleobiogeography

It is difficult to interpret the early Miocene fauna because of the low diversity caused by bad preservation, but it appears to be a relatively cool water fauna which lacks such tropical species as *Globigerinatella insueta* and *Hastigerinella bermudezi*.

The middle Miocene appears also to be represented by a relatively cool water fauna. The dominant keeled *Globorotalia* is *G. miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are distinctive tropical forms, supports this general observation about the assemblages.

The late Miocene up to and including the early Pliocene *G. puncticulata* Zone fauna is represented by relatively cool water faunas. The younger faunas from the early Pliocene to Pleistocene, indicate sporadically warmer conditions, with the influx of *G. tumida* and *Pulleniatina obliquiloculata*.

Major Boundaries

Pliocene/Pleistocene: well marked by the evolutionary first appearance of *Globorotalia truncatulinoides*.

Miocene/Pliocene: is established at this site at the last appearance of *Globorotalia conomiozea* in Core 590A-18; the first appearance of *G. puncticulata* occurs in Sample 590A-17,CC.

Benthic Foraminifers

Benthic foraminifers were examined in the fraction >63 μm in core-catcher samples from Cores 590-1 to 590-3, 590A-1 to 590A-27, and 590B-30 to 590B-53. The larger part of the Miocene section (590A-24 to 590A-27, 590B-30 to 590B-53) was not well preserved, the foraminiferal faunas are impoverished, and in the middle to lower Miocene (590B-35 to 590B-53) there may be as few as six species remaining in the samples. Pliocene faunas are well preserved, particularly in the upper Pliocene. Fluctuations in faunal abundance through the lower Pliocene are probably a function of variations in the otherwise high sedimentation rates.

The most diagenetically altered faunas occur in the *Globorotalia miozea*-*G. fohsi* s.l. Zones (590B-53 to 590B-44,CC). Species apparently resistant to diagenetic dissolution include *Oridorsalis umbonatus, Bolivina subaenariensis, Cibicides rugosus, Melonis barleeanum, Heterolepa kullenbergi*, and *Globocassidulina subglobosa*. These species occur most consistently through the remainder of the Miocene section. Although the majority of appearances and disappearances and the fluctuations in specific abundances are considered an artifact of diagenesis, the disappearance of *Cibicidoides tuxpamensis* at the top of the *Globorotalia fohsi* s.l. Zone (590B-45,CC) is considered real, as it occurs at approximately the same level at Site 588.

The one species which may be indicative of upslope benthic migration, *Melonis pompilioides*, was found in only one interval (590B-34,CC) in the mid-*Neogloboquadrina continuosa* Zone of early late Miocene age.

Radiolarians occur throughout the section from the *Globigerina nepenthes* Zone (590A-25 to 590A-27,CC (mid-late Miocene), to 590B-27 to 590B-47,CC (middle Miocene). They are joined by increased amounts of spicules and a large influx of pyritized worm burrows at 590A-27,CC and 590B-28,CC. These samples contain a unique benthic fauna, more than 50% of which consists of *Rectuvigerina multistriata*, accompanied by *Hopkinsina mioindex* in large numbers, a rare *Buliminella* which occurs only at this level (as at Site 588), and a fauna otherwise similar to those above and below.

At the top of the *Globorotalia conomiozea* Zone, preservation improves, benthic diversity increases, the first miliolids appear (or are preserved), and the first hispido-costate uvigerinids, *Uvigerina hispido-costata* and *U. peregrina*, occur in the faunas. Uvigerinids occur in increased abundance in many areas of the world near the top of the Miocene, for example, in the Canary Current (Lutze, 1979). The fact that a new group colonizes the Site 590 area, a group which will dominate the uvigerinid populations from the late Pliocene through the Quaternary, suggests that conditions resembling those during the glacials developed temporarily during the latest Miocene.

Pliocene benthic faunas contain about 20 to 25 species and closely resemble faunas from the Miocene. Only six new species appear throughout the epoch. Benthics are very abundant in the residues and faunal composition appears to be very similar throughout the section. In the top few samples of Hole 590A, preservation favors even delicate species such as *Anomalina semipunctata*, and the very flattened, spinose morphotype of that taxon found at this site.

A pronounced faunal and sedimentation change occurs at the top of the lower Miocene (590A-7 to 590A-8,CC). *U. hispido-costata* rejoins the faunas, and in the sample directly above, *U. peregrina* reappears, joined by *M. pompilioides*. These benthic changes suggest cooling and upward migration of benthics, which then remain in this area through the course of the Pliocene and into the Quaternary.

The three Quaternary samples (590-1 to 590-3,CC) contain benthic samples similar to those of the Pliocene. Glacial–interglacial cycles may be determinable by the alternating abundances of uvigerinids versus cibicidids and cassidulinids.

Calcareous Nannoplankton

Core-catcher samples, along with additional samples sufficient to accurately determine zonal boundaries, were examined for calcareous nannoplankton. All of the zonal indicators are present, with the exception of *Helicosphaera ampliaperta*. The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis*. Calcareous nannoplankton are abundant throughout the section at

Site 590. Preservation is good in the Quaternary and Pliocene. In the Miocene, preservation deteriorates from moderate to poor, and in particular most of the discoasters are heavily overgrown.

Hole 590

Quaternary

Three cores were obtained before the hole terminated at a depth of 26.2 m BSF. Samples 590-1-1, 5-6 cm to 590-3, 5-6 cm contain *Emiliania huxleyi* and belong in the late Pleistocene *Emiliania huxleyi* Zone (NN21). The late Pleistocene *Gephyrocapsa oceanica* Zone (NN20) includes Samples 590-1-4, 5-6 cm and 590-1-5, 5-6 cm. Samples 590-1,CC to 590-3-2, 5-6 cm contain common *Emiliania ovata* and are placed in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The presence of *Calcidiscus macintyrei* in Samples 590-3-3, 5-6 cm to 590-3,CC places these samples in the lower subzone of the early Pleistocene *E. ovata* Zone (NN19a).

Hole 590A

Quaternary

Sample 590A-1-7, 5-6 cm is placed in the lower subzone of the early Pleistocene *E. ovata* Zone (NN19a) based upon the common occurrences of *E. ovata* and *C. macintyrei*.

Pliocene

The presence of *D. brouweri* from Sample 590A-2-1, 5-6 cm to the last occurrence of *D. pentaradiatus* in 590A-3-1, 5-6 cm places Core 590A-1 to Samples 590A-2-1, 5-6 cm to 590A-2,CC in the late Pliocene *Discoaster brouweri* Zone (NN18). Sample 590A-3-2, 5-6 cm, above the last occurrence of *D. surculus* in Sample 590A-3-2, 5-6 cm, is placed in the late Pliocene *D. pentaradiatus* Zone (NN17). The interval from Samples 590A-3-2, 5-6 cm to 590A-7-3, 0-1 cm, above the last occurrence of *Reticulofenestra pseudoumbilica* in Sample 590A-7-4, 0-1 cm, is placed in the late Pliocene *D. surculus* Zone (NN16).

The early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15) is represented in Samples 590A-7-4, 0-1 cm to 590A-11-7, 0-1 cm, above the last occurrence of *Amaurolithus tricorniculatus* in Sample 590A-11,CC. Samples 590A-11,CC to 590A-14-1, 0-1 cm are placed in the early Pliocene *D. asymmetricus* Zone (NN14), based upon the co-occurrence of *D. asymmetricus* and *A. tricorniculatus*. Sample 590A-14-2, 0-1 cm, below the first occurrence of *D. asymmetricus* to the first occurrence of *Ceratolithus rugosus* in Sample 590A-16-2, 5-6 cm, is placed in the early Pliocene *Ceratolithus rugosus* Zone (NN13). Samples 590A-16-3, 5-6 cm to 590A-18-5, 5-6 cm, are placed in the early Pliocene *Amaurolithus tricorniculatus* Zone (NN12).

Miocene

The co-occurrence of *A. primus* and *D. quinqueramus* in Samples 590A-18-6, 5-6 cm to 590A-27,CC places these samples in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). Hole 590A ended with Core 590A-27 at a depth of 280.8 m BSF.

Hole 590B

Hole 590B begins at the top of the section in Zone NN20; therefore, only core-catcher samples were examined until Zone NN11b was reached.

Miocene

The first occurrence of *A. primus* is in Sample 590B-30-3, 5-6 cm. Therefore the boundary between the upper and lower subzone of the late Miocene *D. quinqueramus* Zone (NN11a/b) is between this sample and Sample 590B-30-4, 5-6 cm. The interval from Sample 590B-30-4, 5-6 cm to the first occurrence of *D. quinqueramus* in Sample 590B-35-5, 5-6 cm is placed in the lower subzone of the late Miocene *D. quinqueramus* Zone (NN11a). The interval between the first occurrence of D. quinqueramus in Sample 590B-35-5, 5-6 cm and the last occurrence of *D. hamatus* in Sample 590B-38,CC is placed in the middle Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus* from Samples 590B-38,CC to 590B-40,CC places these samples in the middle Miocene *D. hamatus* Zone (NN9). Samples 590B-41-5, 5-6 cm and 590B-41,CC, above the first occurrence of *Catinaster coalitus*, are placed in the middle Miocene *Catinaster coalitus* Zone (NN8). The interval from Samples 590B-42-1, 5-6 cm and 590B-45-1, 5-6 cm, above the first occurrence of *D. kugleri*, is placed in middle Miocene *D. kugleri* Zone (NN7). Samples 590B-45-3, 5-6 cm to 590B-47-3, 5-6 cm, above the last occurrence of *Sphenolithus heteromorphus* in Sample 590B-47-5, 5-6 cm, are placed in the middle Miocene *D. exilis* Zone (NN6). The first occurrence of *D. exilis* in Sample 590B-49,CC places Samples 590B-47-5, 5-6 cm to 590B-49,CC in the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). Samples 590B-50-1, 5-6 cm to 590B-50,CC, above the last occurrence of *S. belemnos* in Sample 590B-51-1, 5-6 cm, are placed in the early Miocene *Helicosphaera ampliaperta* Zone (NN4). The interval from the last occurrence of *S. belemnos* in Sample 590B-51-1, 5-6 cm to the last occurrence of *Triquetrorhabdulus carinatus* in Sample 590B-52,CC, is placed in the early Miocene *S. belemnos* Zone (NN3). The co-occurrence of *T. carinatus* and *D. druggii* in Samples 590B-52,CC and 590B-53-1, 5-6 cm places these samples in the early Miocene *D. druggii* Zone (NN2). The absence of *D. druggii* and the presence of *T. carinatus* in Samples 590B-53-3, 5-6 cm to 590B-53,CC places these samples in the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1). Drilling was terminated at a depth of 499.1 m BSF.

PALEOMAGNETISM

The paleomagnetic properties of sediments from this site were generally similar to those of previous Leg 90 sites, except that there is more evidence of viscous overprinting and long-term remagnetization.

Holes 590 and 590A were subsampled at three specimens per section, and 590B was subsampled at two per section of HPC cores and one per section of XCB cores (590A-28 onward). The Kuster orientation tool was deployed in Holes 590A and 590B with success rates of 60 and 48%, respectively. To date, laboratory NRM measurements have been completed on one specimen per section from Holes 590 and 590A (Table 3). The pattern of intensity variation is: (1) high values (1 to 5 μG) in the oxidized surface Subunit IA, Core 590-1, (2) medium intensities (about 0.1 μG) in Subunit IB, Cores 590-2 to 590-5, and (3) very low intensities (0.005 to 0.1 μG) in the remainder of Hole 590A. The last region is characterized by very high accumulation rates during the late Pliocene; they dilute the detrital ferromagnetic component. Depths at which high-intensity spikes were noted are reported in Table 4.

A polarity stratigraphy can be traced back to 4 m.y. (Fig. 8); it is consistent with the microfossil zonations. The Olduvai Event is poorly resolved. Prior to 4 m.y. ago, inclinations are consistently shallower than the expected axial dipole value, and show a definite negative (normal) bias. This must be a consequence of viscous overprinting and/or authigenic growth of magnetic minerals on a time scale which is long compared with the average polarity interval of about 3 × 10^5 yr. Authigenic iron sulfides are common throughout the section and probably reflect authigenic growth.

SEDIMENTATION RATES

Sedimentation rates are determined by calcareous nannoplankton boundaries and their ages, as discussed in the Introduction.

At Site 590, three holes were drilled in present-day water depths of about 1300 m. The first two holes cover the recent to late Miocene (NN11b) interval down to 280.8 m (Fig. 9). Hole 590B duplicated this interval and was terminated at 499.1 m, after penetrating lower upper Miocene to lower Miocene calcareous sediments. In Hole 590B only core catchers were investigated from 0 to about 280 m sub-bottom, and calculated sedimentation rates are less reliable in this particular interval (dashed line in Fig. 10).

In the early Miocene (Hole 590B, NN1 to top of NN3) the sedimentation rate is 14.4 m/m.y. in indurated calcareous sediments. Between Samples 590B-50,CC and 590B-51-1, the sedimentation rate changes, reaching 29.4 m/m.y. in the middle Miocene (Hole 590B, NN5 to NN7 top) (Fig. 10). The sedimentation rate in the late middle Miocene to early Pliocene interval (Hole 590B, NN7 top to NN13 top) is based on seven datum levels and is 29.1 m/m.y., also in calcareous sediments (Fig. 10). Then a rather remarkable increase to 56.7 m/m.y. was noted in the early to late Pliocene calcareous sequence in Hole 590A (NN13 top to NN18 top), based on five datum levels (Fig. 9). In the Quaternary (Holes 590 and 590A, above NN18 top) the sedimentation rate drops to 19.9 m/m.y. (Fig. 9), probably because of winnowing, as sediments are somewhat coarser than below.

Sedimentation rates in the upper part of Hole 590B, in which only core-catcher samples were investigated, are similar to those of Holes 590 and 590A for the early to late Pliocene (52.4 m/m.y.) and for the Quaternary (17.2 m/m.y.).

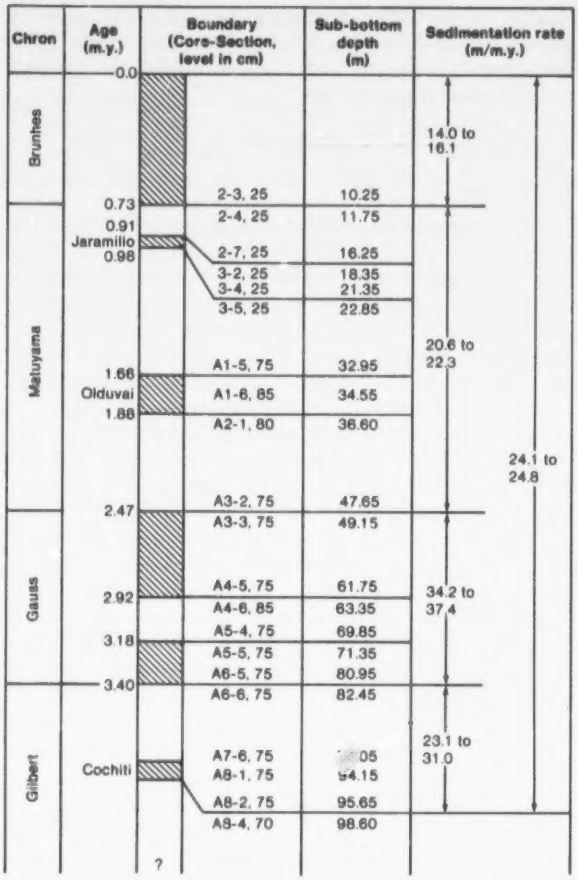

Chron
Age (m.y.)
Boundary (Core-Section, level in cm)
Sub-bottom depth (m)
Sedimentation rate (m/m.y.)
Brunhes
Matuyama
Gauss
Gilbert
0.0
0.73
0.91
Jaramillo
0.98
1.66
Olduvai
1.88
2.47
2.92
3.18
3.40
Cochiti
?
2-3, 25
2-4, 25
2-7, 25
3-2, 25
3-4, 25
3-5, 25
A1-5, 75
A1-6, 85
A2-1, 80
A3-2, 75
A3-3, 75
A4-5, 75
A4-6, 85
A5-4, 75
A5-5, 75
A6-5, 75
A6-6, 75
A7-6, 75
A8-1, 75
A8-2, 75
A8-4, 70
10.25
11.75
16.25
18.35
21.35
22.85
32.95
34.55
36.60
47.65
49.15
61.75
63.35
69.85
71.35
80.95
82.45
05
94.15
95.65
98.60
14.0 to 16.1
20.6 to 22.3
24.1 to 24.8
34.2 to 37.4
23.1 to 31.0

Figure 8. Magnetic polarity stratigraphy and sedimentation rates for Hole 590 and the upper part of Hole 590A. The Olduvai Subchron is poorly resolved.

Table 3. Laboratory NRM measurements, Holes 590 and 590A.

	Hole 590	Hole 590A
Geometric mean intensity (μG)	0.335	0.045
Scalar mean inclination (± 1 s.d.)	−26.5 ± 39.0°	−12.9 ± 37.6°
Axial dipole inclination	−50.9	
Mean angle between repeats		6.1°

Table 4. High intensity magnetization spikes in Holes 590 and 590A.

Sample (level in cm)	Sub-bottom depth (m)	Intensity (μG)
Hole 590		
2-7, 25	16.25	3.375
Hole 590A		
6-5, 75	80.95	0.353
14-6, 75	159.25	0.534
21-6, 75	226.45	0.244
23-6, 75	245.65	0.378
25-5, 75	263.35	0.391

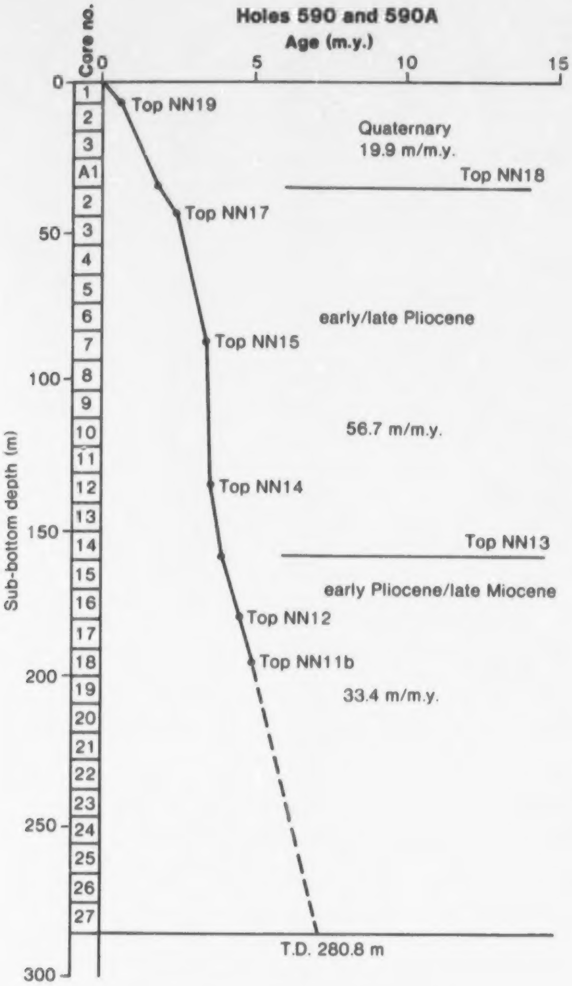


Figure 9. Sedimentation rates in Holes 590 and 590A.

SUMMARY AND CONCLUSIONS

Site 590 lies to the east of the crest of Lord Howe Rise. This site was selected as one of several that make up a north-south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites forming a depth traverse to study changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m).

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. It occupies a shallow-water, transitional position between warm subtropical waters to the north (Site 588) and temperate sites to be drilled further south and provides an important section for correlation between these sites.

Site 590 consists of three holes (Fig. 11): Hole 590, which was continuously cored with the HPC from 0-26.2 m sub-bottom; Hole 590A, which was continuously cored with the HPC from 26.2-280.8 m sub-bottom; and Hole 590B, which was continuously cored with the HPC from 0-250.7 m sub-bottom and rotary drilled with the XCB from 250.7-499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. The primary and persistent disturbance exists as a zone of soupy sediments usually 20-30 cm in thickness, at the top of each core. In a few cores inflow has caused highly disturbed intervals in the upper one or two sections, but a very high percentage of the core lengths are mechanically undisturbed sediments. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. The value of the cores obtained using the extended core barrel is that at most levels the sediment biscuits do not seem to have been moved far from their original stratigraphic positions, in contrast with conventional rotary coring which, in the less consolidated layers, creates clear vertical disturbance within each core.

The three holes drilled at Site 590 provide a complete calcareous sequence from early Miocene through Recent (Fig. 11), with the exception of an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorotalia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 does not occur at this site. A paleomagnetic polarity stratigraphy has been identified down to the middle part of Gilbert Chron (about 4.2 m.y. ago).

The section (Fig. 11) is represented mostly by foraminifer-bearing nannofossil ooze (or chalk) or foraminifer-rich nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, with greatest abundance (1 to 5%) in the early late Miocene (Cores 590B-32 to 590B-35). The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasional sponge spicules.

The sequence contains only traces of nonbiogenic components, but clear volcanic ash is quite persistent. Numerous light green laminae from early late Miocene to early Miocene may be altered volcanic ash layers. Much of the sequence is very light gray to white ooze and chalk. Zones richer in foraminifers are darker gray to light olive gray. Bioturbation is moderate in the early Miocene, intense in the middle to early late Miocene, moderate in the late late Miocene and only slight in the Pliocene and Quaternary.

The sediment becomes more indurated with depth. Sediments above 275 m sub-bottom (middle late Miocene) consist of ooze which becomes progressively stiffer with depth. Sediments below ~275 m sub-bottom are chalk, with clear recrystallization seen in the early Miocene (Cores 590B-51 to 590B-53).

The sequence at Site 590 is divided into three subunits (Fig. 11) based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm sub-bottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer-nannofossil ooze, and repre-

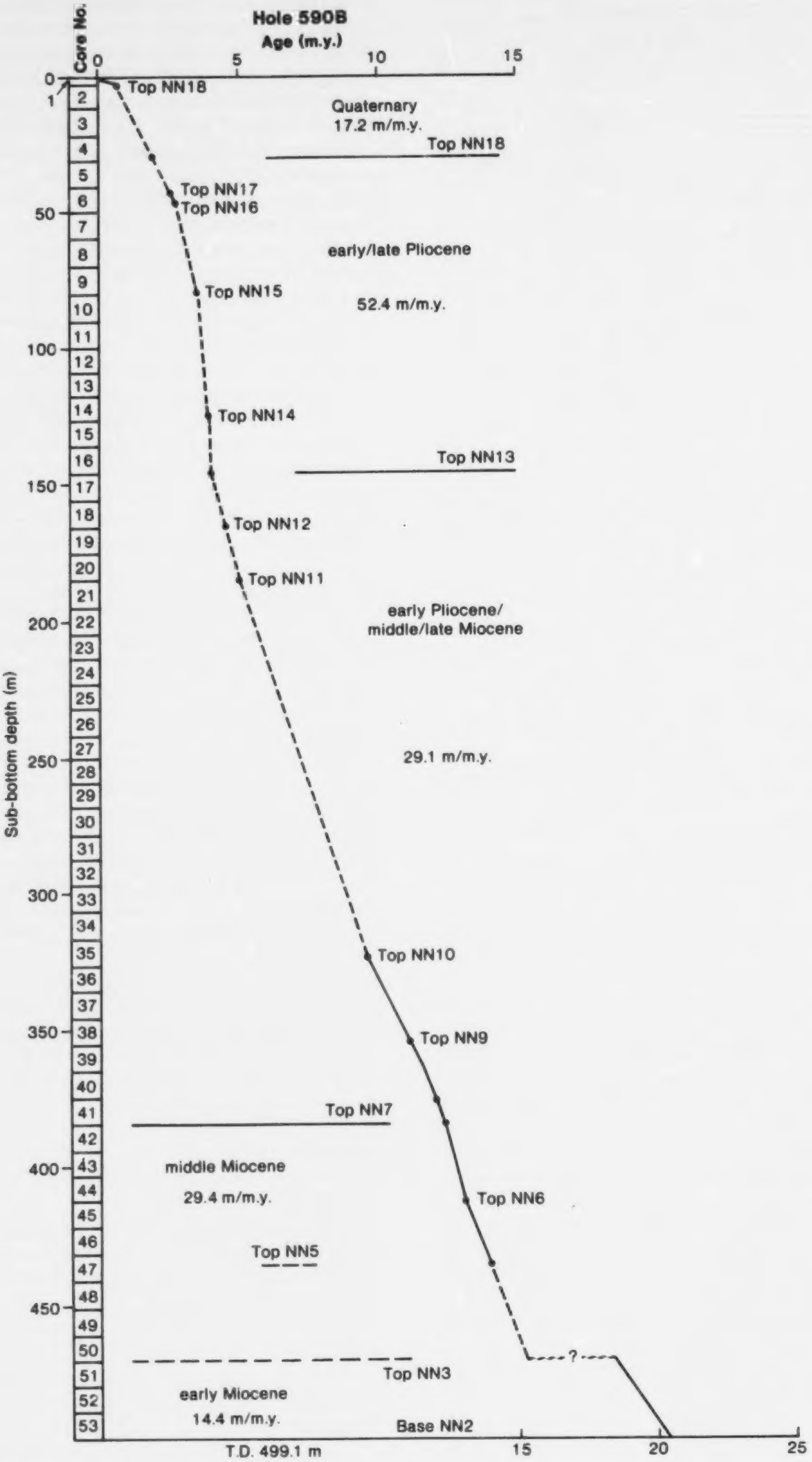


Figure 10. Sedimentation rates in Hole 590B.

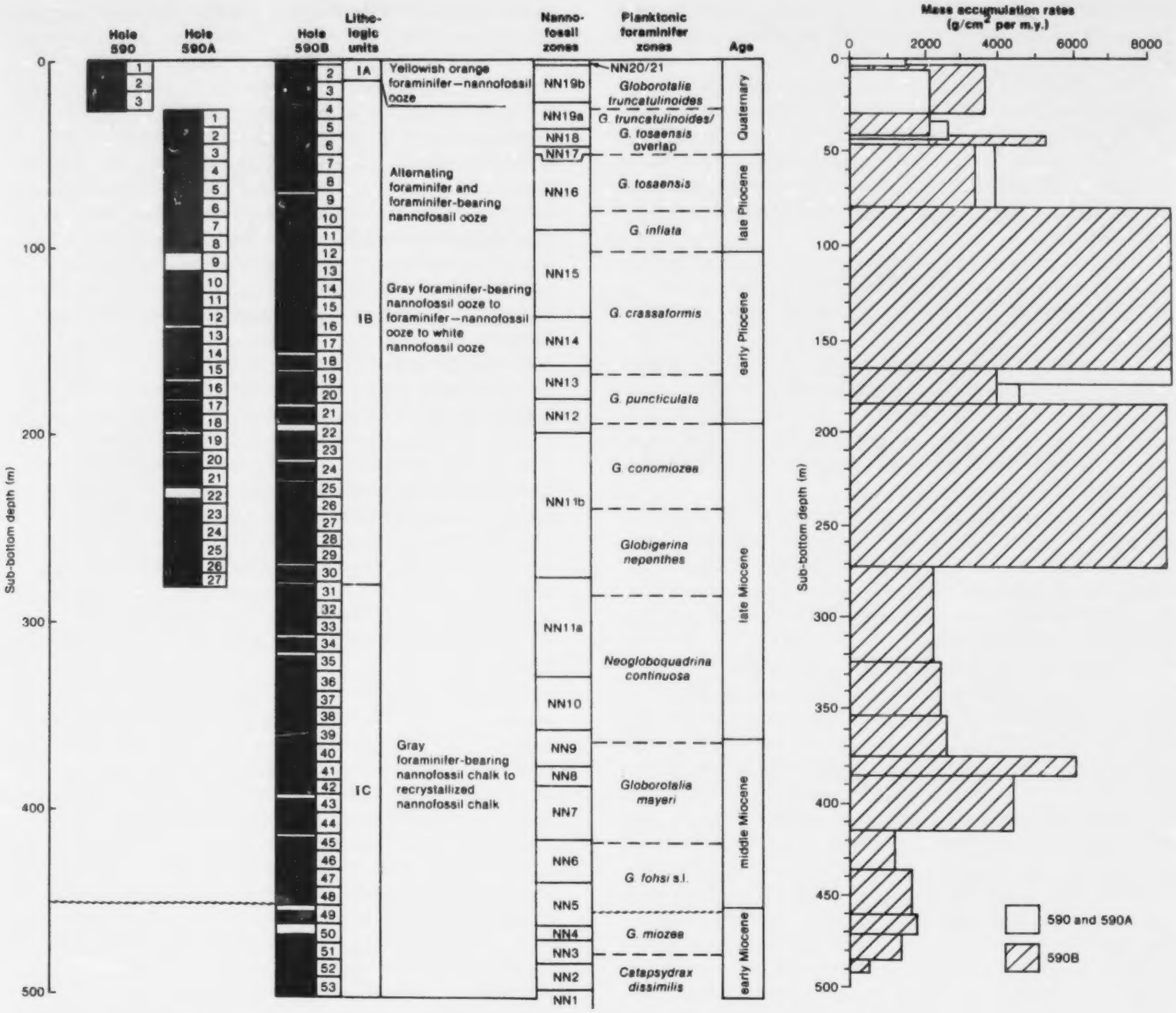


Figure 11. Summary lithology, biostratigraphy, and mass accumulation rates of Site 590. Recovery in black.

sents the zone of oxidation and possible current winnowing activity near the sediment/water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing nannofossil ooze and layers of light olive gray foraminifer-nannofossil ooze. The change in percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom-current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional foraminifer-bearing nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this subunit, which resembles the upper part of Subunit IB in consisting of alternating, very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to chalk. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450–499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk, lacks the foraminifer-rich layers of the portion above, and is less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

Site 590 provides a superb stratigraphic sequence of calcareous microfossils for the middle Miocene and younger. Biostratigraphic zonal sequences of transitional type occur in combination with an important temperate component. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene.

It is difficult to interpret the early Miocene fauna because of the low diversity arising from bad preservation, but it appears to be a temperate fauna lacking tropical species.

The middle Miocene appears also to be represented by a temperate fauna. The dominate keeled globorotaliid is *Globorotalia miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are clear tropical forms, support this general observation of the assemblages.

The fauna of the late Miocene, up to and including the early Pliocene *Globorotalia puncticulata* Zone, is also represented mostly by temperate faunas. The younger faunas from the early Pliocene to Pleistocene were sporadically warmer, with the influx of *G. tumida* and *Pulleniatina obliquiloculata*.

Preservation of calcareous nannoplankton is good in the upper part of the sequence (Quaternary–Pliocene) and moderate (late Miocene) to poor (early middle Miocene) in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the early Miocene unconformity and very poor below. The benthic foraminifers are well-preserved throughout much of the sequence; however, below the late Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

At Site 590 the Pliocene/Quaternary and Miocene/Pliocene boundaries are well represented and the late Neogene exhibits clear, gradual, evolutionary sequences within some lineages. This is particularly noticeable for the *Globorotalia (Globoconella)* lineage, with clear transitions from *G.* (*G.*) *conoidea* (= *G. miotumida*) to *G.* (*G.*) *conomiozea* to *G. puncticulata sphericomiozea* to *G. puncticulata* to *G. inflata*. At nearby Site 206, much of the lineage was missing in the hiatus associated with the Miocene/Pliocene boundary.

Benthic foraminifers occur throughout the sequence but with varying quality of preservation. In the early and middle Miocene, as few as six species remain following diagenetic dissolution. Diversity increases in the early part of the late Miocene and preservation is only moderately good. Preservation improves in the middle late Miocene and assemblages are very well preserved in the Pliocene and Quaternary.

Paleoenvironmental History of Site 590

Neogene sediments at Site 590, near the crest of Lord Howe Rise, were laid down in a pelagic, open-ocean environment at middle bathyal depths that have changed little during the last 23 m.y. Calcareous oozes were deposited in a relatively uncomplicated environment at these shallow depths, and with virtually no terrigenous sedimentary influences other than traces of fine eolian sediments and more common and fluctuating input of volcanic ash. During this time, very little siliceous biogenic material was preserved in the sediment, although almost certainly there was moderate siliceous productivity by plankton in the overlying surface waters. In this region, the Neogene planktonic foraminiferal assemblages are dominated by temperate rather than tropical elements, although the latter exhibit brief incursions of greater abundance.

During the early Miocene, from about 23 to 16 m.y., there were low rates of sedimentation (14 m/m.y.) in this area, and hiatus-forming erosion occurred fairly briefly at about 17.5 and 16.5 m.y. A scarcity of foraminifers in this interval probably resulted from diagenetic dissolution rather than from changes in productivity or dissolution. The earliest Miocene at this site represents an acme of explosive volcanicity in the source regions, judging from a large number of altered volcanic ash layers. Explosive volcanicity of sufficient intensity to form visible ash layers continued through to the early late Miocene, but at lower intensities than during the early late Miocene.

During the middle to early late Miocene (15 to 8 m.y.), sedimentation rates of calcareous biogenic materials increased significantly to about 30 m/m.y. and no hiatus-forming erosion occurred. This situation resulted from decreased bottom-water erosion in the ocean, although deposition of more foraminifer-rich horizons in otherwise foraminifer-bearing nannofossil ooze indicates intervals where bottom-water activity was sufficiently intense to cause winnowing of fine sediments. During this interval, bioturbation was the highest of the entire Neogene, suggesting that organic material was delivered at a higher rate to the ocean floor.

During the late late Miocene (8 m.y.) to the middle Pliocene (3 m.y.) rates of calcareous sediment deposition increased even further to a surprisingly high 57 m/m.y. At this time, rather uniform nannofossil oozes were laid down. Few of the more foraminifer-rich levels were deposited. The lithofacies suggests deposition in a rather uniform environment on the ocean floor, mostly lacking the episodes of increased bottom-water activity that occurred during other times of the Neogene. Bioturbation decreased to moderate levels. The rather uniform depositional conditions were not matched by surface water, which, in contrast, exhibited great paleoceanographic change. For example, during the latest Miocene, from 6 to 5 m.y., the planktonic foraminiferal assemblages became distinctly cooler as temperate waters migrated northward across the area. There were also decreases in faunal diversity and in average specimen size. The latest Miocene cooling is well documented elsewhere, including areas to the south of Site 590 (Kennett and Vella, 1975). At the same time, the first hispido-costate uvigerinids appeared within the benthic foraminifer assemblages. Uvigerinids appeared in increased abundances in many areas of the world's oceans in the latest Miocene in association with the δC^{13} shift (Keigwin, 1979), which reflected important paleoceanographic changes. Since these uvigerinids become more typical on a permanent basis in late Pliocene to Quaternary benthic foraminiferal assemblages, their presence suggests that conditions resembling the glacials developed temporarily during the latest Miocene.

The middle Pliocene (3 m.y.) to Quaternary represents the latest phase of paleoenvironmental evolution at Site 590. About 3 m.y. ago, a pronounced sediment change occurred which is marked by greater winnowing of the fine-grained sediment fraction at certain intervals in alternation with calcareous-nannofossil-rich, foraminifer-poor layers. The succession again indicates episodes of enhanced bottom-water activity alternating with quieter episodes. Sedimentation rates responded by decreasing to 17-20 m/m.y., which is quite low for this area.

The hispido-costate uvigerinids returned on a permanent basis by upward migration from greater depths during a cooling episode. Large-scale oscillations occurred in surface water masses, with brief incursions of relatively warm subtropical assemblages into sequences otherwise dominated by temperate elements.

The youngest part of this interval, which is at and close to the sediment/water interface (upper 40 cm), is winnowed, oxidized, and more foraminifer-rich. This represents the latest of a succession of such layers, which reflect an increase in bottom-water activity. Older such intervals in the section have since undergone chemical reduction and inferred color change from brown to light olive gray.

The changes in sedimentation and in benthic foraminiferal faunas ~3 m.y. ago certainly were related to widespread paleoceanographic changes in the ocean associated with global climatic cooling. At that time bottom waters intensified in activity even at the shallow-water depths of Site 590, and cooler, deeper waters migrated upwards to shallow intermediate depths.

One of the surprises resulting from drilling at Site 590 was the high sedimentation rate (uncorrected for sediment porosity) in largely calcareous biogenic intervals, especially during the Pliocene (50-57 m/m.y.).

The seismic profile in the area shows no clear ponding of sediments for much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, spectacularly high in the Pliocene, are due to high levels of calcareous biogenic productivity.

REFERENCES

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Keigwin, L. D., Bender, M. L., and Kennett, J. P., 1979. Thermal structure of the deep Pacific Ocean in the early Pliocene. *Science* 205:1386-1388.

Kennett, J. P., and Vella, P., 1975. Late Cenozoic planktonic foraminifera and paleoceanography at DSDP Site 284 in the cool subtropical South Pacific. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 769-799.

Lutze, G. F., 1979. Neogene benthonic foraminifera from Site 369, Leg 41, Deep Sea Drilling Project. *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP*, 41: Washington (U.S. Govt. Printing Office), 659-667.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor. I. L., 1974. *Bathymetry of the South Pacific.* IMR Technical Reports, Scripps Institution of Oceanography, La Jolla, California.

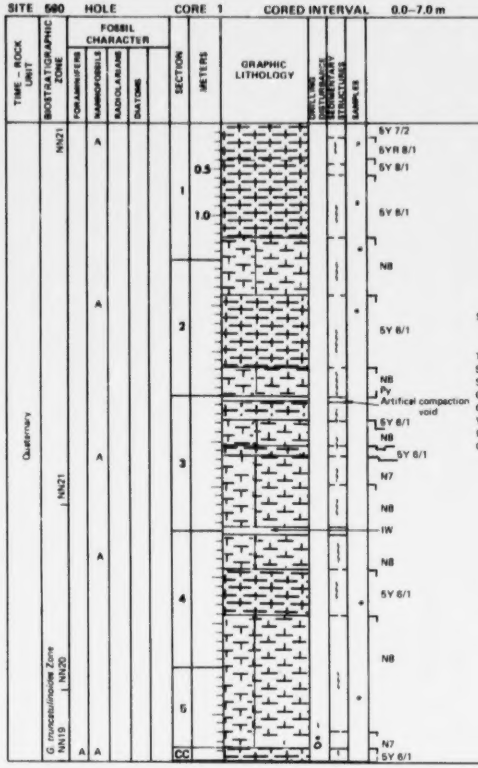
Sclater, J. G., Meinke, L., Bennett, A., and Murphy, C., in press. The depth of the ocean through the Neogene. *In* Kennett, J. P. (Ed.), *The Miocene Ocean: Paleoceanography and Biogeography.* Geol Soc. Am. Mem., 163.

Srinivasan, M. S., and Kennett, J. P., 1981. A review of Neogene planktonic foraminiferal biostratigraphy: applications in the equatorial and South Pacific. *In* Warme, J. E., Douglas, R. G., and Winterer, E. L., (Eds.), *The Deep Sea Drilling Project: A Decade of Progress.* Soc. Econ. Paleontol. Mineral. Spec. Publ., 32:395-432.

Willcox, J. B., Symonds, P. A., Hinz, K., and Bennett, D., 1980. Lord Howe Rise, Tasman, Sea—preliminary geophysical results and petroleum prospects. *B.M.R. J. Aust. Geol. Geophys.*, 5:225-236.

Date of Acceptance: 1 December 1983

SITE 590 HOLE CORE 1 CORED INTERVAL 0.0–7.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21
NN21
G. truncatulinoides Zone
NN20
NN19
A
A
A
A
A
A
1
2
3
4
5
CC
0.5
1.0
5Y 7/2
5YR 8/1
5Y 8/1
5Y 8/1
N8
5Y 8/1
N8
Py
Artifical compaction void
5Y 6/1
N8
5Y 6/1
N7
N8
IW
N8
5Y 6/1
N8
N7
5Y 6/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, yellowish gray (oxidized) zone, soft. No obvious burrowing, contacts gradational.

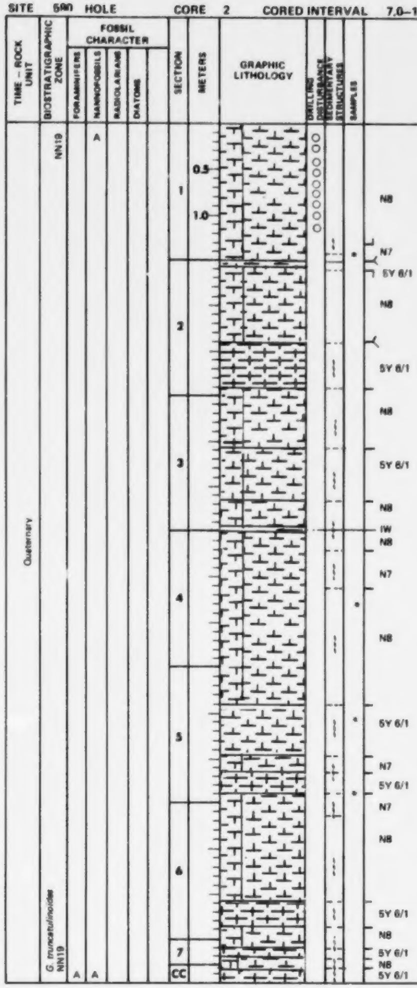
FORAMINIFER-NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N8), soft, no obvious burrowing, occasional blebs of iron sulfide, contacts gradational.

SMEAR SLIDE SUMMARY:

	1, 22 D	1, 90 D	1, 132 D	4, 71 D	5, 33 D	2, 49 M
Texture:						
Sand	C	C	C	C	R	C
Silt	A	A	C	C	C	A
Clay	A	A	A	A	D	A
Composition:						
Volcanic glass	–	–	–	C	–	–
Foraminifers	A	A	C	A	C	A
Calc. nannofossils	A	A	A	A	D	A

SITE 590 HOLE CORE 2 CORED INTERVAL 7.0–16.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19
G. truncatulinoides
NN19
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
N7
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
IW
N8
N7
N8
5Y 6/1
N7
5Y 6/1
N7
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1

LITHOLOGIC DESCRIPTION

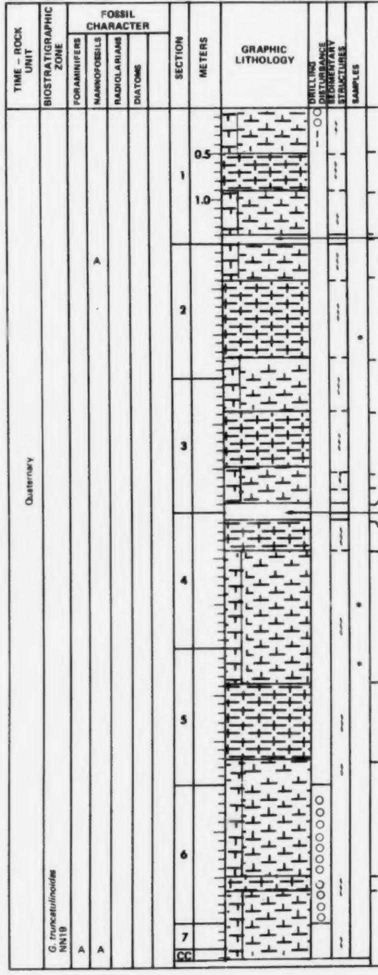
FORAMINIFER-BEARING, NANNOFOSSIL OOZE, light gray (N8), soft, occasional burrows and iron sulfide blebs and streaks.

FORAMINIFER-NANNOFOSSIL OOZE, soft, light olive gray (5Y 6/1), occasional burrows and iron sulfide blebs and streaks.

SMEAR SLIDE SUMMARY:

	1, 134 D	4, 78 D	5, 53 D	5, 150 M
Texture:				
Sand	C	–	R	C
Silt	A	C	C	A
Clay	A	D	A	A
Composition:				
Carbonate unspec.	–	R	R	R
Foraminifers	A	C	A	A
Calc. nannofossils	A	D	A	A

SITE 590 HOLE CORE 3 CORED INTERVAL 16.6–26.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5Y 6/1
N8
Void
N8
5Y 6/1
N8
5Y 6/1
N7
N8
Artifical gap
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8

LITHOLOGIC DESCRIPTION

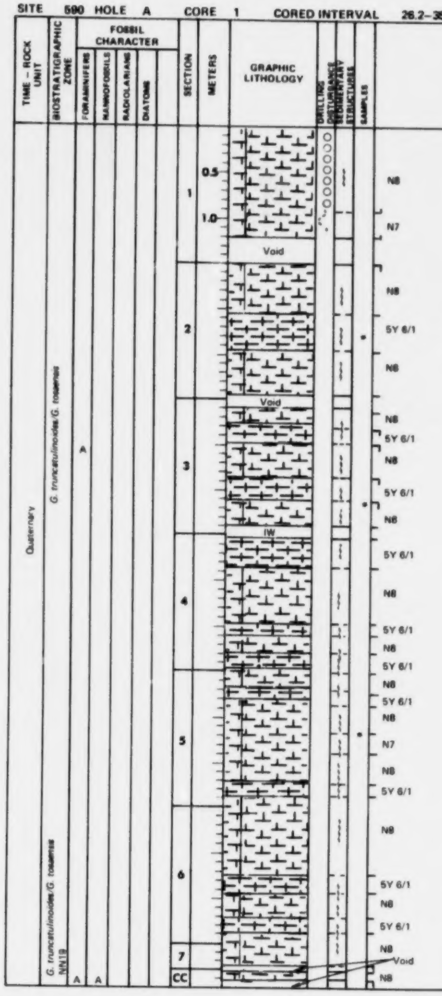
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, periodic burrows.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft, occasional blebs and streaks of pyrite and burrowing activity.

SMEAR SLIDE SUMMARY:

	2, 104	4, 106	5, 16
	D	D	M
Texture:			
Sand	C	R	R
Silt	A	C	C
Clay	A	D	D
Composition:			
Pyrite	–	–	R
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE A CORE 1 CORED INTERVAL 26.2–35.8


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
G. truncatulinoides/G. tosaensis
NN19
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
Void
IW
N8
N7
N8
5Y 6/1
N8
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
N7
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
Void
N8

LITHOLOGIC DESCRIPTION

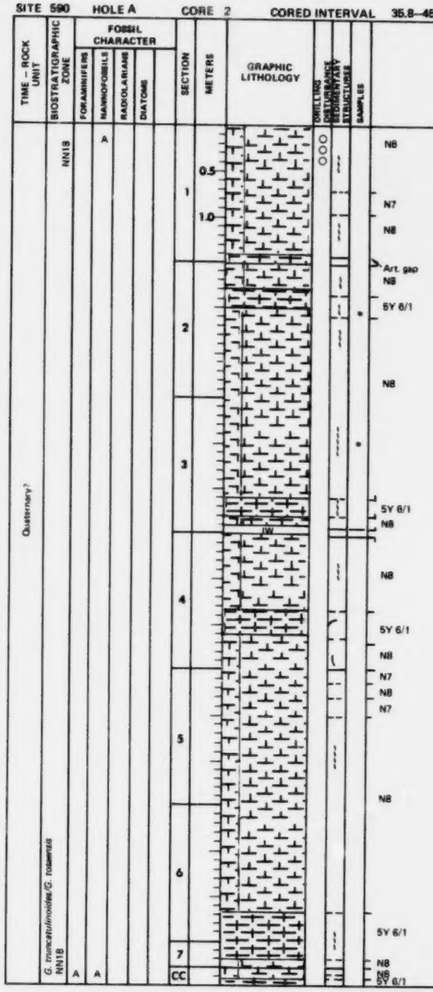
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, occasional burrows.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), higher percentage of forams, soft, occasional blebs and streaks of pyrite and burrows.

SMEAR SLIDE SUMMARY:

	2, 80	3, 114	5, 71
	D	D	D
Texture:			
Sand	C	R	R
Silt	A	C	C
Clay	A	D	D
Composition:			
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE A CORE 2 CORED INTERVAL 35.8–45.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary?
NN18
G. truncatulinoides/G. tosaensis
NN18
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
IW
N8
N7
N8
Art. gap
N8
5Y 6/1
N8
5Y 6/1
N8
N8
5Y 6/1
N8
N7
N8
N7
N8
5Y 6/1
N8
N8
5Y 6/1

LITHOLOGIC DESCRIPTION

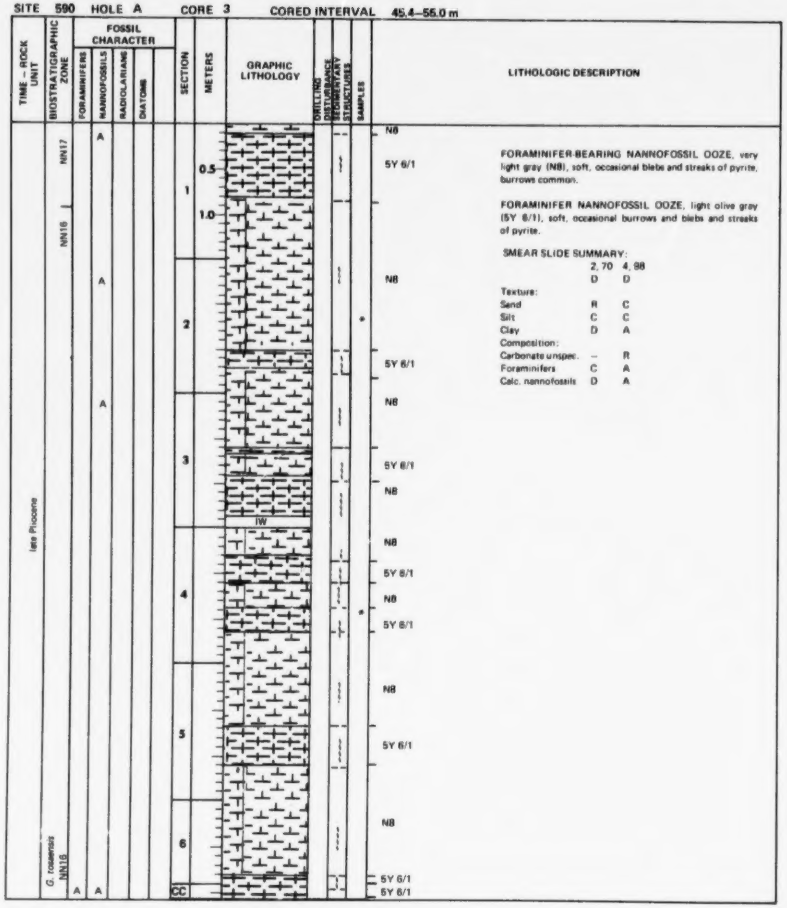
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7), soft, occasional burrows and streaks and blebs of pyrite.

NANNOFOSSIL FORAMINIFER OOZE, light olive gray (5Y 6/1), soft, occasional burrows and streaks and blebs of pyrite.

SMEAR SLIDE SUMMARY:

	2, 51	3, 95
	D	D
Texture:		
Sand	C	R
Silt	A	C
Clay	A	D
Composition:		
Foraminifers	A	C
Calc. nannofossils	A	D

SITE 590 HOLE A CORE 3 CORED INTERVAL 45.4–55.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN17
NN16
G. tosaensis
NN16
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
IW
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
N8
5Y 6/1
5Y 6/1

LITHOLOGIC DESCRIPTION

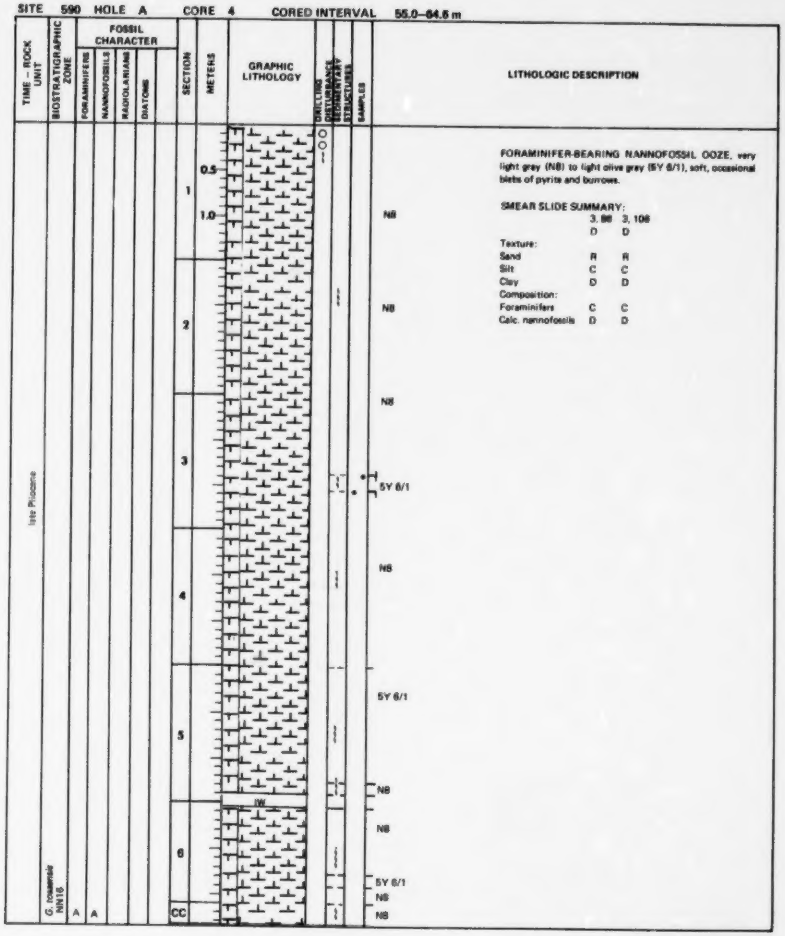
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, burrows common.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft, occasional burrows and blebs and streaks of pyrite.

SMEAR SLIDE SUMMARY:

	2, 70	4, 98
	D	D
Texture:		
Sand	R	C
Silt	C	C
Clay	D	A
Composition:		
Carbonate unspec.	–	R
Foraminifers	C	A
Calc. nannofossils	D	A

SITE 590 HOLE A CORE 4 CORED INTERVAL 55.0–64.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. tosaensis
NN16
A
A
1
2
3
4
5
6
CC
0.5
1.0
IW
N8
N8
N8
5Y 6/1
N8
5Y 6/1
N8
N8
5Y 6/1
N8
N8

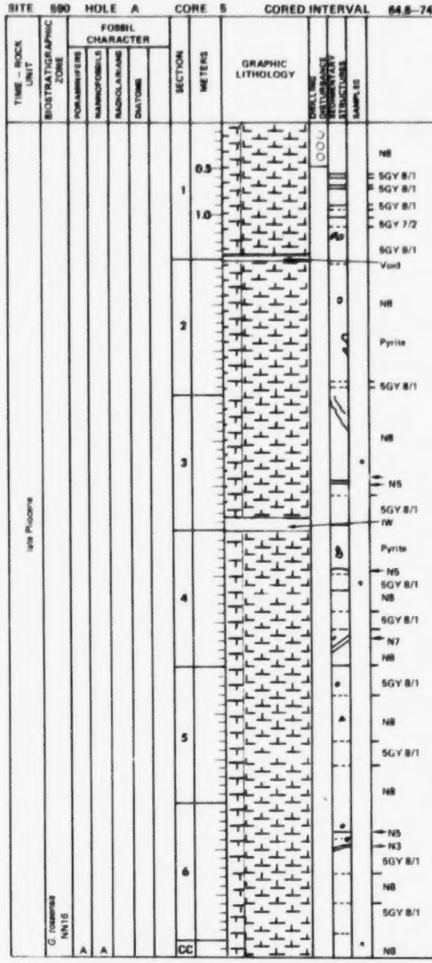
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light olive gray (5Y 6/1), soft, occasional blebs of pyrite and burrows.

SMEAR SLIDE SUMMARY:

	3, 96	3, 106
	D	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 5 CORED INTERVAL 64.6–74.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. tosaensis
NN16
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5GY 8/1
5GY 8/1
5GY 8/1
5GY 7/2
5GY 8/1
Void
N8
Pyrite
5GY 8/1
N8
N5
5GY 8/1
IW
Pyrite
N5
5GY 8/1
N8
5GY 8/1
N7
N8
5GY 8/1
N8
5GY 8/1
N8
N5
N3
5GY 8/1
N8
5GY 8/1
N8

LITHOLOGIC DESCRIPTION

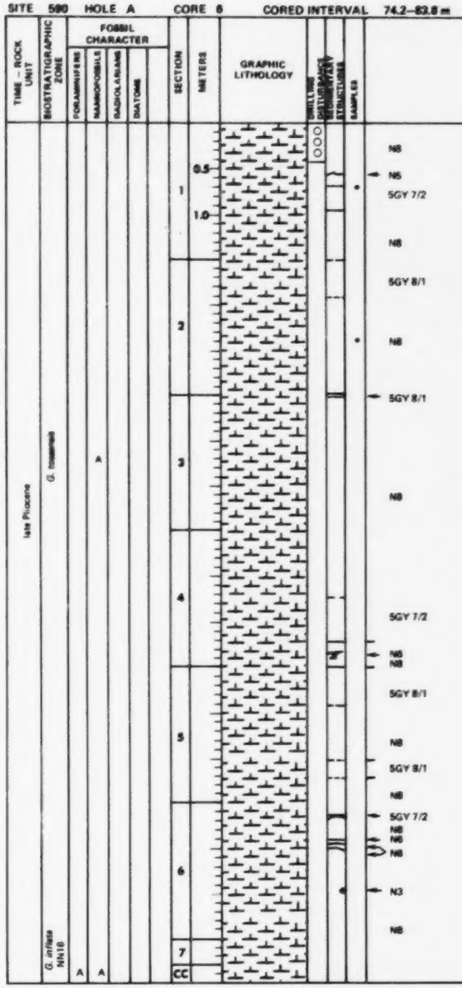
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1), dark (N5) spots and streaks throughout the entire core (←iron sulfide minerals), undefined burrows, near 30–40 cm (Section 6) *Planolites*.

SMEAR SLIDE SUMMARY

	3, 80	4, 58	CC[1]
	D	D	M
Composition:			
Quartz	–	–	T
Feldspar	–	–	T
Heavy minerals	–	T	–
Clay	–	–	R
Volcanic glass	–	T	A
Palagonite	–	–	R
Pyrite	–	–	C
Foraminifers	C	C	–
Calc. nannofossils	A	A	–
Fish remains	–	–	T

[1] Insol. residue

SITE 590 HOLE A CORE 6 CORED INTERVAL 74.2–83.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. tosaensis
G. inflata
NN16
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
N5
5GY 7/2
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 7/2
N5
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 7/2
N8
N6
N8
N3
N8

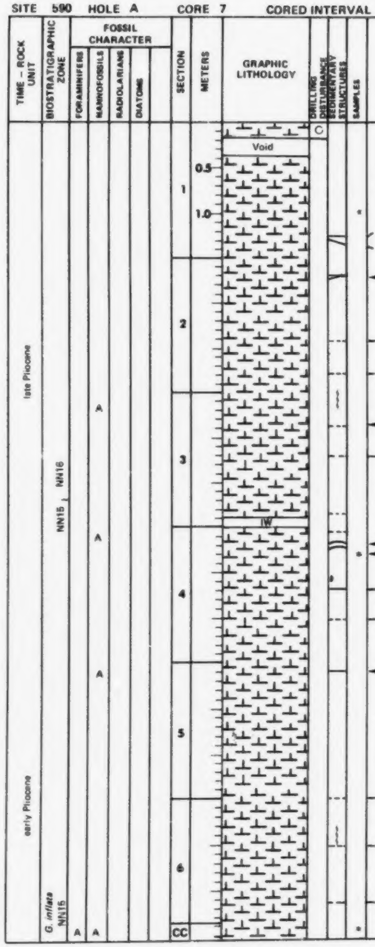
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to grayish yellow green (5GY 7/2), dark (N4–N5) spots and streaks throughout the entire core (→ iron sulfide) undefined burrows.

SMEAR SLIDE SUMMARY:

	1, 72	2, 92
	D	D
Composition:		
Volcanic glass	R	R
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 7 CORED INTERVAL 83.8–93.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
early Pliocene
NN15 , NN16
G. inflata
NN15
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
Void
C
IW
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N8/N9
5GY 8/1
5GY 8/1
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N9
5GY 8/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1) dark (N5) spots throughout the core.

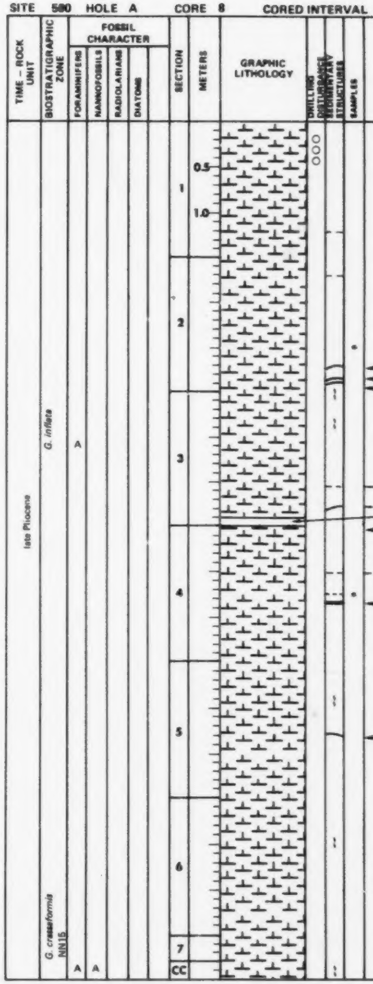
Note: H_2S odor when splitting Section 4.

SMEAR SLIDE SUMMARY:

	1, 110 D	4, 29 D	CC[1] M
Composition:			
Quartz	–	–	T
Feldspar	–	–	T
Clay	–	–	R
Volcanic glass	T	–	A
Pyrite	T	T	C
Foraminifers	R	R	–
Calc. nannofossils	D	D	–
Sponge spicules	–	T	–

[1] Insol. residue

SITE 590 HOLE A CORE 8 CORED INTERVAL 93.4–103.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
G. crassaformis
NN15
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5GY 7/2
N8
N5
5GY 7/2
N5
N8
5G 8/1
IW
N5
N8
5GY 7/2
5GY 7/2
N8
N6
N8

LITHOLOGIC DESCRIPTION

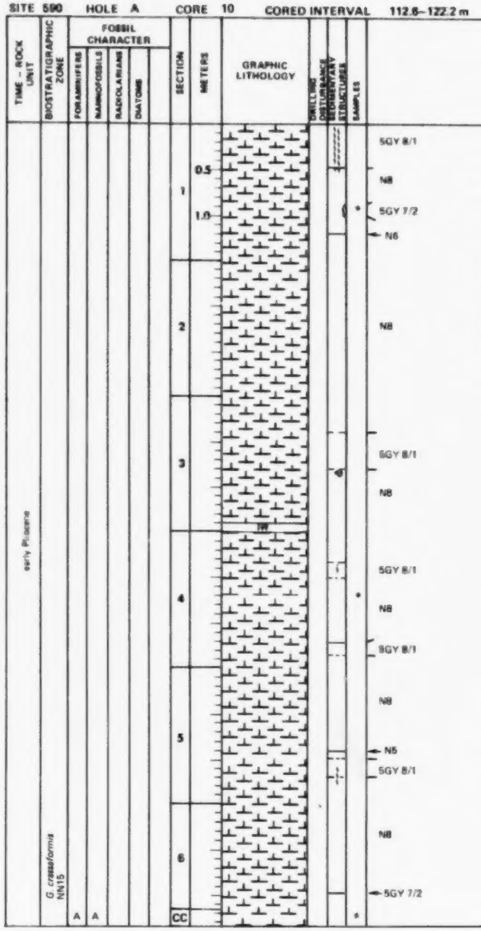
NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1) and grayish yellow green (5GY 7/2) iron sulfide spots (N5) throughout the entire core; gradational color changes; bioturbation rare.

SMEAR SLIDE SUMMARY:

	2, 105 D	4, 82 M
Composition:		
Volcanic glass	T	T
Palagonite	T	–
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	D	D

Core 9, 103.0–112.6 m: no recovery.

SITE 590 HOLE A CORE 10 CORED INTERVAL 112.6–122.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis NN15
A
A
0.5
1.0
1
2
3
4
5
6
CC
IW
5GY 8/1
N8
5GY 7/2
N6
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N8
N5
5GY 8/1
N8
5GY 7/2

LITHOLOGIC DESCRIPTION

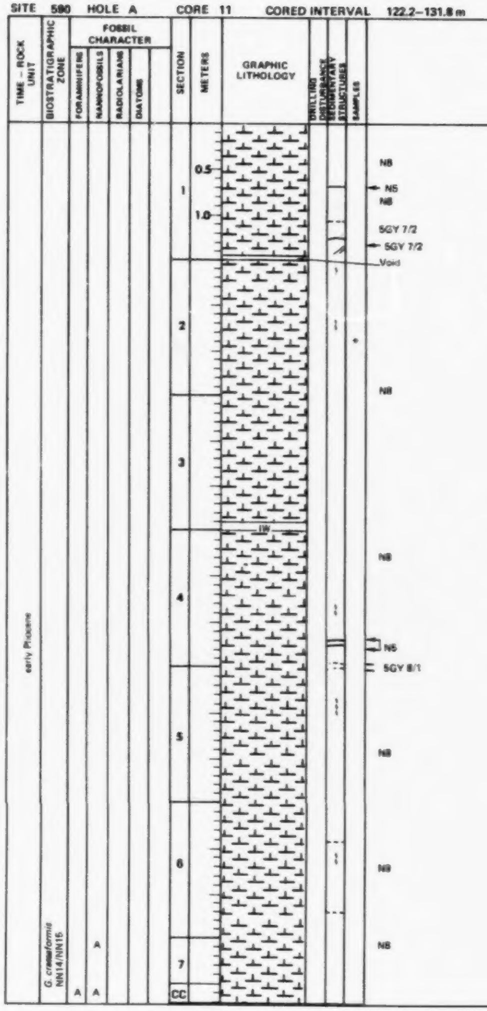
NANNOFOSSIL OOZE, soft, light greenish gray (5GY 8/1) to very light gray (N8); dark (N5) spots throughout the entire core (iron sulfide); top of the core intensively bioturbated.

SMEAR SLIDE SUMMARY

	1, 93 M	4, 75 D	CC[1] M
Composition:			
Quartz	–	–	C
Feldspar	–	–	C
Volcanic glass	T	T	C
Palagonite	–	–	T
Pyrite	T	–	C
Foraminifers	R	T	–
Calc. nannofossils	D	D	–
Other	–	–	A

[1] Insol. residue

SITE 590 HOLE A CORE 11 CORED INTERVAL 122.2–131.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis NN14/NN15
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
IW
N8
N5
N8
5GY 7/2
5GY 7/2
Void
N8
N8
N5
5GY 8/1
N8
N8
N8

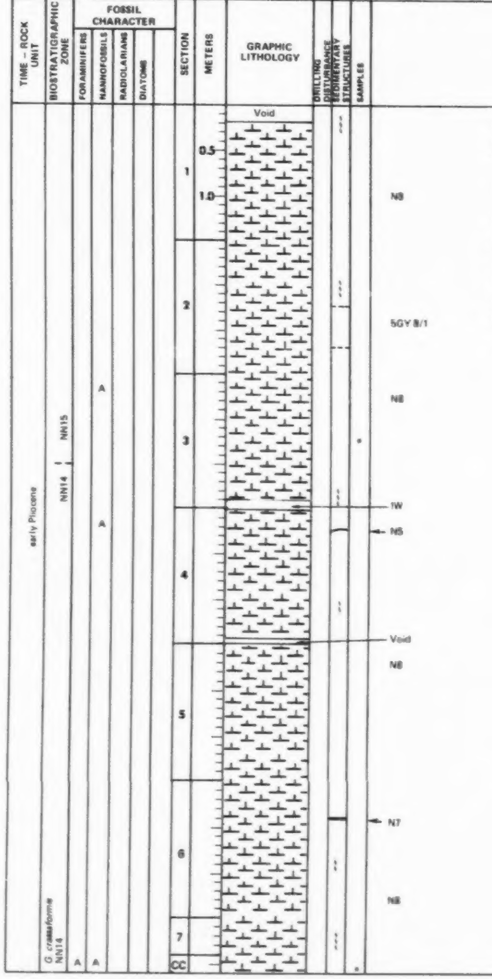
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots and streaks throughout the entire core (—iron sulfide), some unidentified burrows.

SMEAR SLIDE SUMMARY:

	2, 72 D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 12 CORED INTERVAL 131.8–141.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN14
NN15
G. crassaformis
NN14
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
5GY 8/1
N8
IW
N5
Void
N8
N7
N8

LITHOLOGIC DESCRIPTION

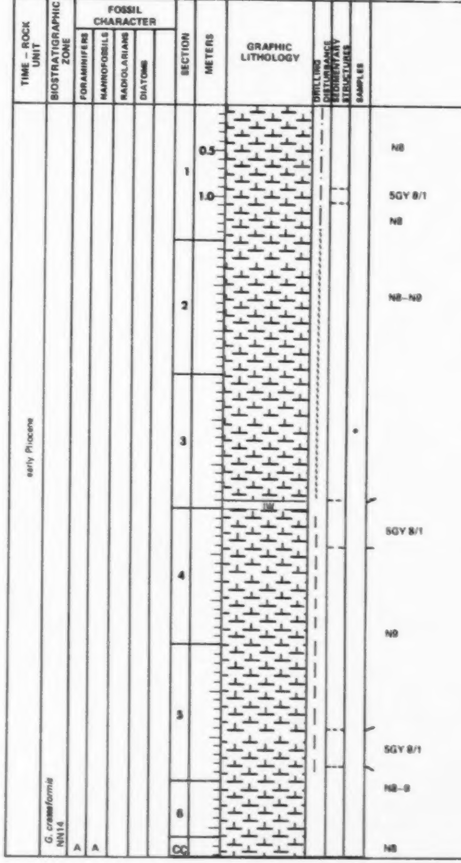
NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots and streaks throughout the entire core, some unidentified burrows.

SMEAR SLIDE SUMMARY:

	3, 80	CC[1]
	D	M
Composition:		
Quartz	–	R
Feldspar	–	R
Heavy minerals	–	T
Volcanic glass	T	R
Pyrite	T	R
Foraminifers	R	–
Calc. nannofossils	D	–
Other	–	A

[1] Insol. residue

SITE 590 HOLE A CORE 13 CORED INTERVAL 141.4–151.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN14
A
A
1
2
3
4
5
6
CC
0.5
1.0
IW
N8
5GY 8/1
N8
N8–N9
5GY 8/1
N9
5GY 8/1
N8–9
N8

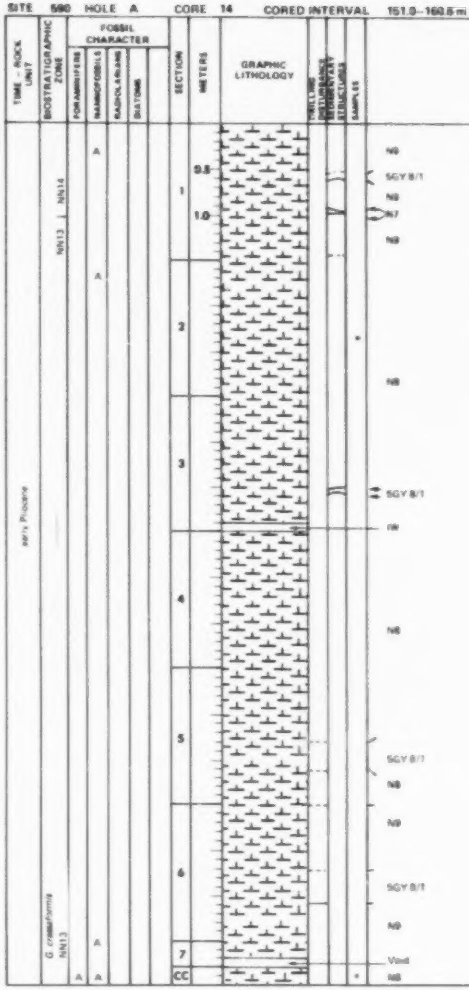
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots rare, core slightly to very deformed.

SMEAR SLIDE SUMMARY:

	3, 71
	D
Composition:	
Quartz	T
Feldspar	T
Palagonite	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 14 CORED INTERVAL 151.0–160.6 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN13 | NN14
G. crassaformis
NN13
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N9
5GY 8/1
N9
N7
N9
N8
5GY 8/1
N9
N8
5GY 8/1
N8
N9
5GY 8/1
N9
Void
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to light greenish gray (5GY 8/1), dark (N5) spots and streaks throughout the entire core, bioturbation rare.

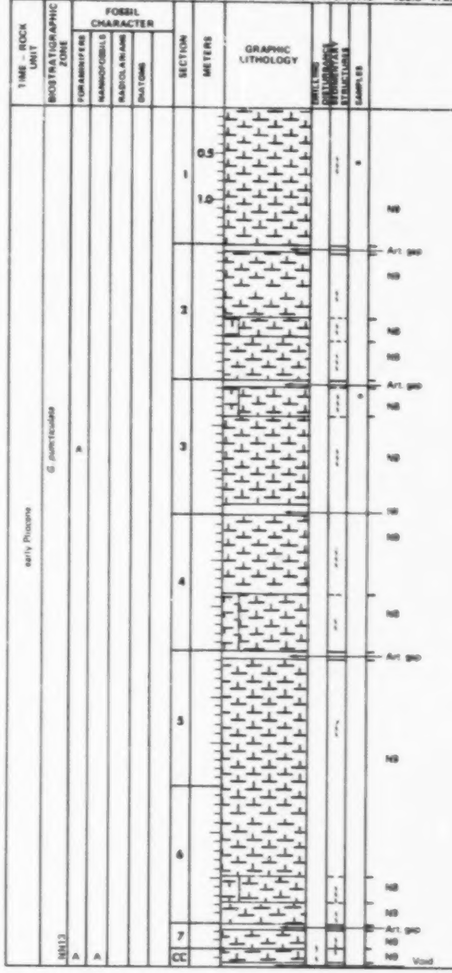
Note: H_2S odor when splitting Sections 2 and 3.

SMEAR SLIDE SUMMARY

	2, 80	CC[1]
Composition:	D	M
Quartz	–	R
Feldspar	–	R
Volcanic glass	T	A
Pyrite	–	R
Foraminifers	R	–
Calc. nannofossils	D	–
Fish remains	T	–
Other	–	A

[1] Insolub. residue

SITE 590 HOLE A CORE 15 CORED INTERVAL 160.6–170.2 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN13
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N9
Art. gap
N9
N8
N9
Art. gap
N9
N9
N8
N9
N9
Art. gap
N9
N8
N9
Art. gap
N9
N9
Void

LITHOLOGIC DESCRIPTION

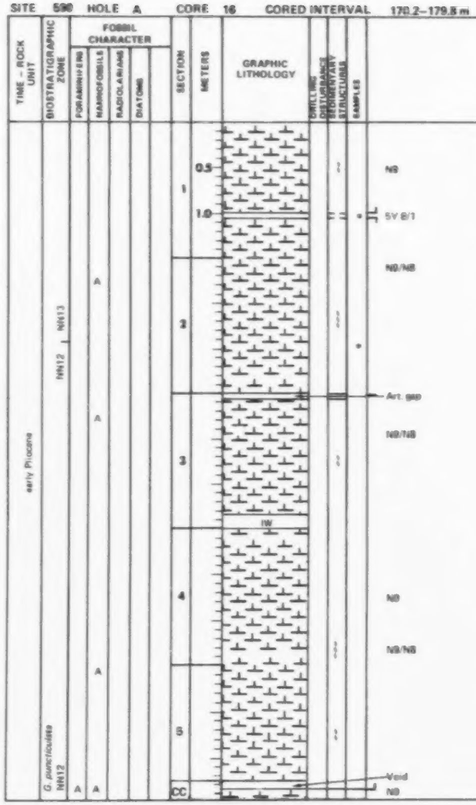
NANNOFOSSIL OOZE, white (N9), soft, moderately burrowed throughout, occasional streaks and halos of pyrite.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, moderate to heavy burrowing, occasional streaks or halos of pyrite.

SMEAR SLIDE SUMMARY:

	1, 87 D	3, 16 D
Texture:		
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 16 CORED INTERVAL 170.2–179.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN12 | NN13
G. puncticulata
NN12
A
A
A
A
A
1
2
3
4
5
CC
0.5
1.0
IW
N9
5Y 8/1
N8/N8
Art. gap
N9/N8
N9
N9/N8
Void
N9

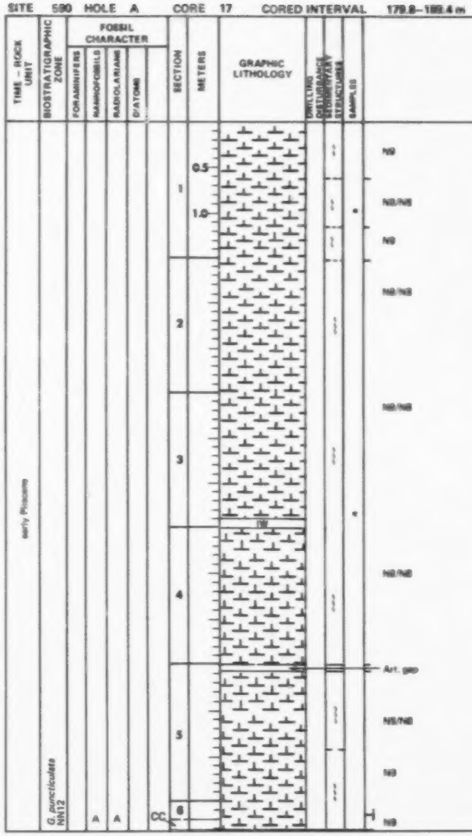
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray/white (N8/N9), soft, occasional burrows and pyrite halos. Burrows are yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	1, 97	2, 83
	M	D
Texture:		
Sand	R	–
Silt	C	C
Clay	D	D
Composition:		
Mica	R	–
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 17 CORED INTERVAL 179.8–189.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN12
A
A
1
2
3
4
5
6
CC
0.5
1.0
IW
N9
N8/N8
N9
N8/N8
N8/N8
N8/N8
Art. gap
N8/N8
N9
N9

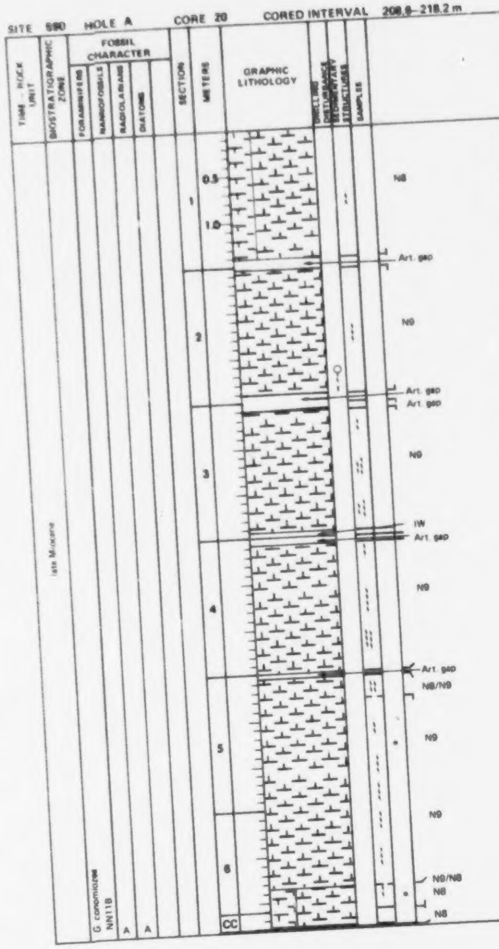
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8) throughout, soft, yellowish gray (5Y 8/1) burrows and pyrite streaks periodically throughout.

SMEAR SLIDE SUMMARY:

	3, 135	1, 91
	M	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 20 CORED INTERVAL 208.8–218.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN11B
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
Art. gap
N9
Art. gap
Art. gap
N9
IW
Art. gap
N9
Art. gap
N8/N9
N9
N9
N9/N8
N8
N8

LITHOLOGIC DESCRIPTION

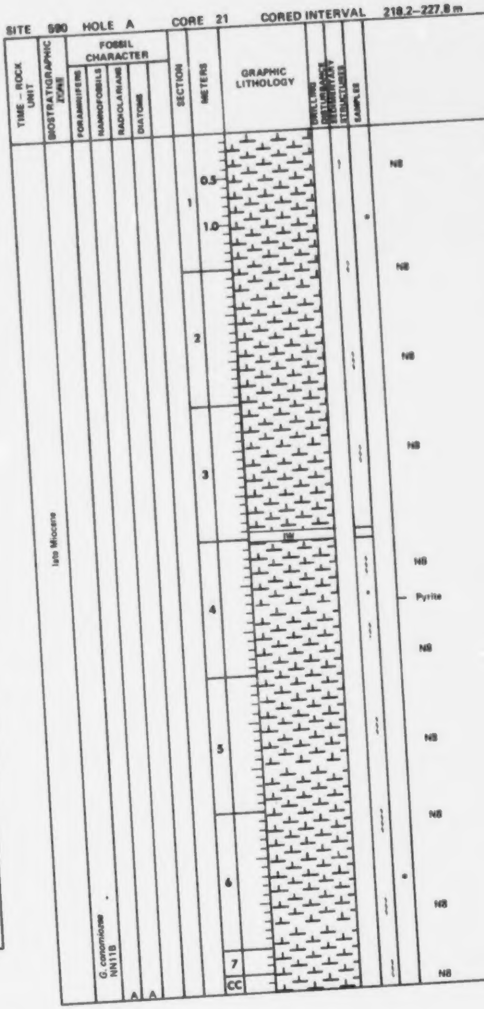
NANNOFOSSIL OOZE, white (N9), soft, pyrite streaks and burrows, yellowish gray (5Y 8/1).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray zones (N7), soft, burrows and pyrite streaks throughout.

SMEAR SLIDE SUMMARY

	5, 70 D	6, 96 D
Texture		
Sand	–	R
Silt	R	C
Clay	D	D
Composition		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 21 CORED INTERVAL 218.2–227.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN11B
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
IW
N8
N8
N8
N8
N8
Pyrite
N8
N8
N8
N8
N8

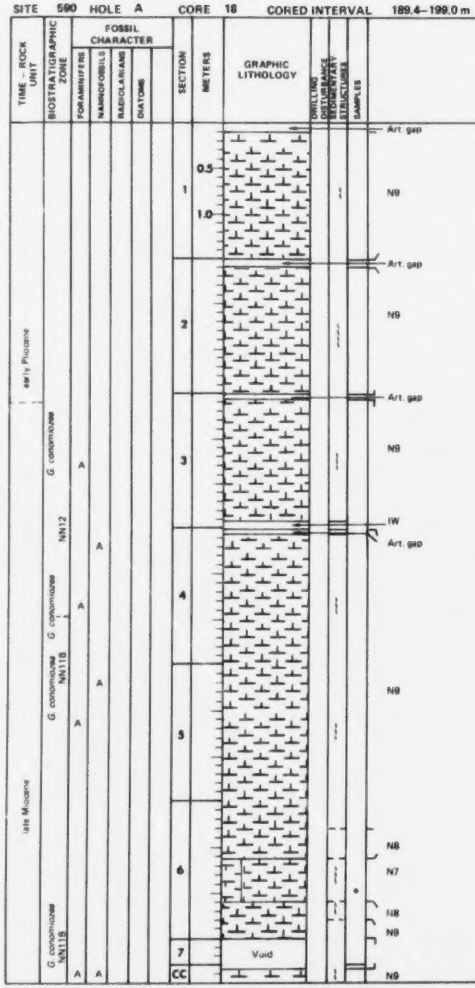
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed, burrows yellowish gray (5Y 8/1), pyrite streaks throughout, one pyrite concretion.

SMEAR SLIDE SUMMARY:

	1, 96 D	6, 70 D
Texture:		
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 18 CORED INTERVAL 189.4–199.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
G. conomiozea
NN12
G. conomiozea
G. conomiozea
NN11B
G. conomiozea
NN11B
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
Art. gap
N9
Art. gap
N9
Art. gap
N9
IW
Art. gap
N9
N8
N7
N8
N9
N9

LITHOLOGIC DESCRIPTION

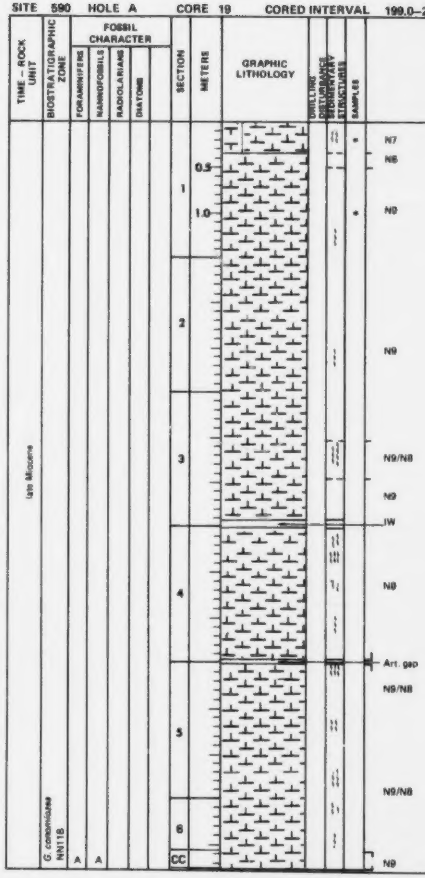
NANNOFOSSIL OOZE, white (N9), soft, with periodic burrows yellowish gray (5Y 8/1), pyrite streaks and burrows throughout.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N7), soft, occasional burrows and pyrite streaks.

SMEAR SLIDE SUMMARY:

	3, 87	6, 91
	D	D
Texture:		
Sand	–	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 19 CORED INTERVAL 199.0–208.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN11B
A
A
1
2
3
4
5
6
CC
0.5
1.0
N7
N8
N9
N9
N9/N8
N9
IW
N9
Art. gap
N9/N8
N9/N8
N9

LITHOLOGIC DESCRIPTION

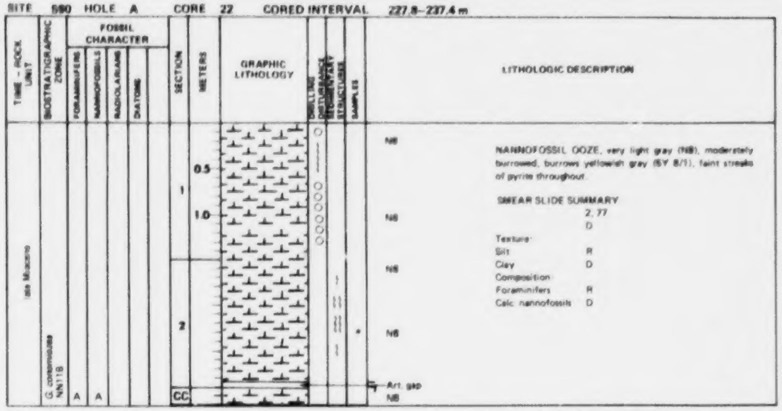
FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N7), soft, burrows and pyrite streaks common.

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, moderate to heavy burrowing, pyrite streaks common.

SMEAR SLIDE SUMMARY:

	1, 12	1, 98
	D	D
Texture:		
Sand	R	–
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 22 CORED INTERVAL 227.8–237.4 m

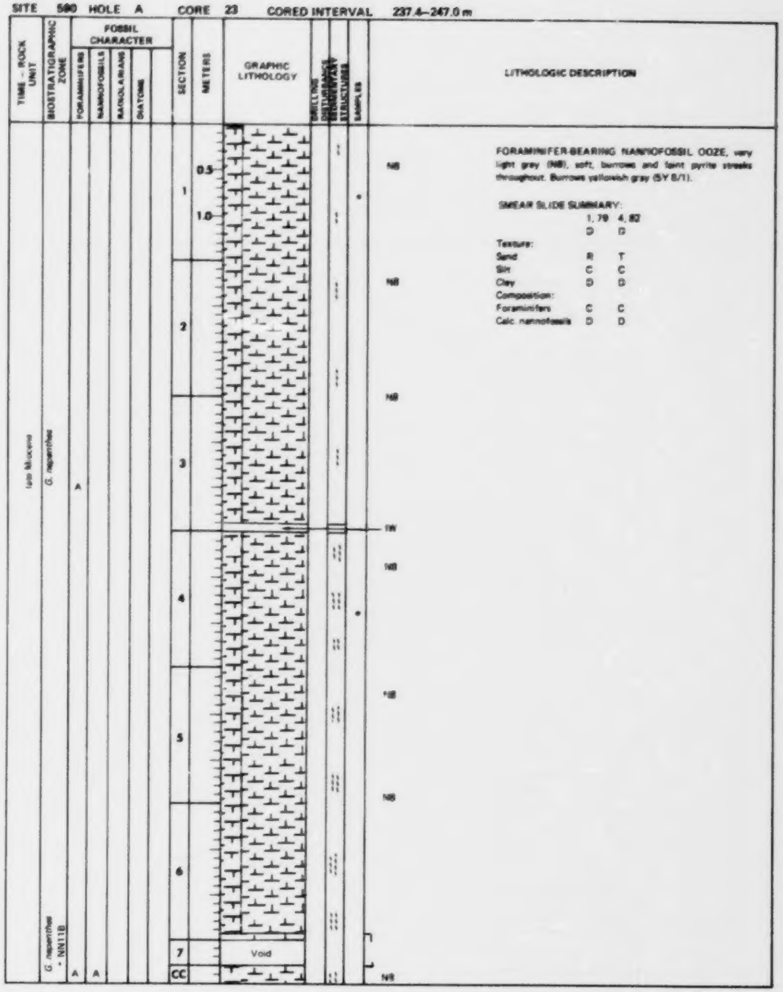

TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. conomiozea
NN11B
A
A
1
2
CC
0.5
1.0
N8
N8
N8
N8
Art. gap
N8

NANNOFOSSIL OOZE, very light gray (N8), moderately burrowed, burrows yellowish gray (5Y 8/1), faint streaks of pyrite throughout.

SMEAR SLIDE SUMMARY

	2, 77
	D
Texture:	
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 23 CORED INTERVAL 237.4–247.0 m

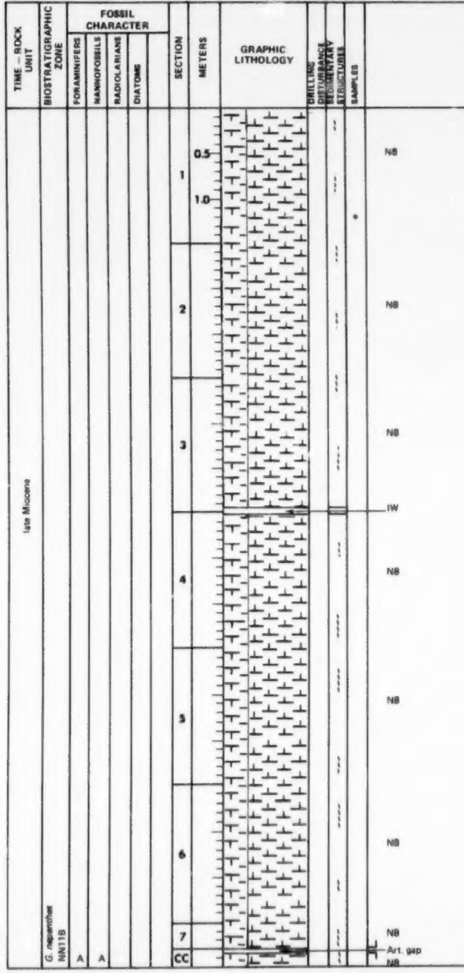

TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. nepenthes
A
G. nepenthes - NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
N8
N8
IW
N8
N8
N8
N8

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, burrows and faint pyrite streaks throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	1, 79	4, 82
	D	D
Texture:		
Sand	R	T
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 24 CORED INTERVAL 247.0–256.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes NN11B
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
N8
N8
IW
N8
N8
N8
N8
Art. gap
N8

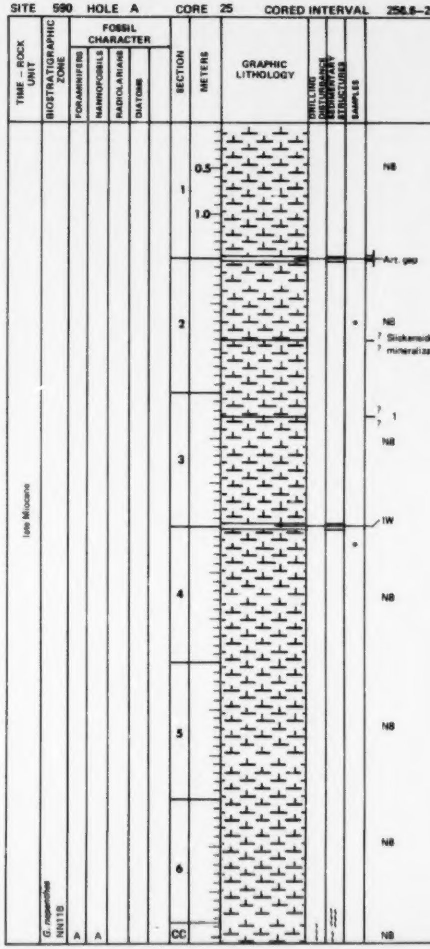
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light grey (N8), soft to stiff, moderate to light burrowing throughout, burrows yellowish grey (5Y 8/1), faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	1, 118	4, 21
	D	D
Texture:		
Sand	T	T
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 25 CORED INTERVAL 256.6–266.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes NN11B
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
Art. gap
N8
? 1
N8
IW
N8
N8
N8
N8

? Slickensided joint with
? mineralization along joint[1] or coring artifact!

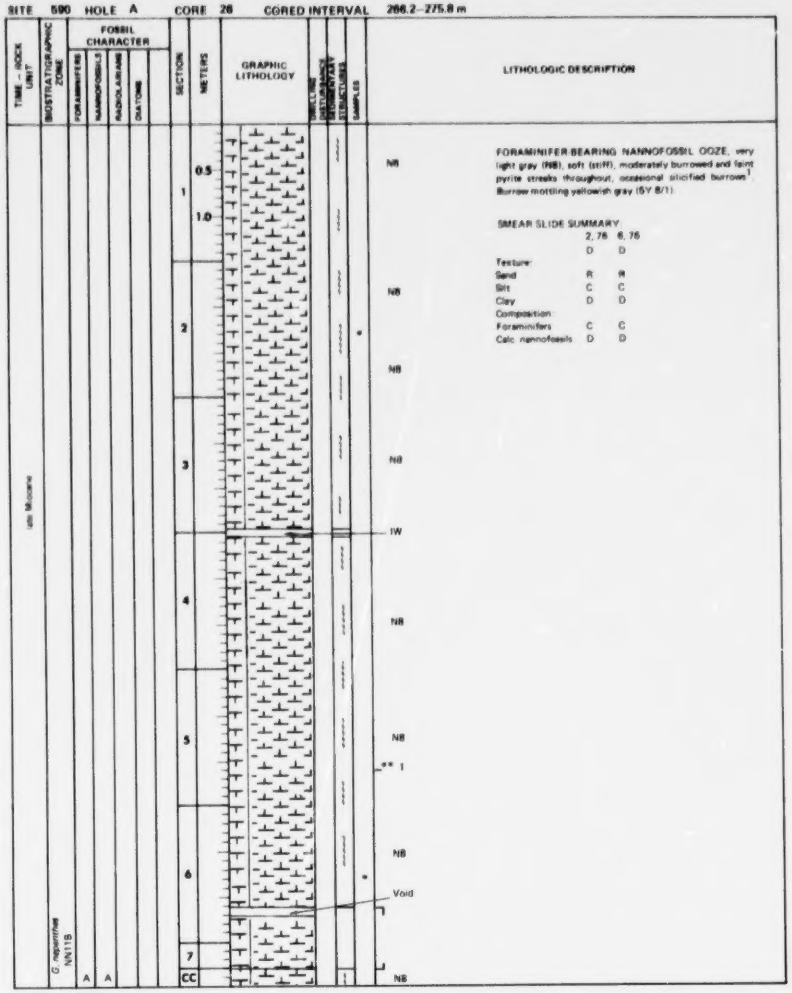
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed, faint streaks of pyrite, burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 71	4, 21
	D	M
Texture:		
Sand	T	R
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 28 CORED INTERVAL 266.2–275.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
N8
N8
N8
IW
N8
N8
N8
Void
N8

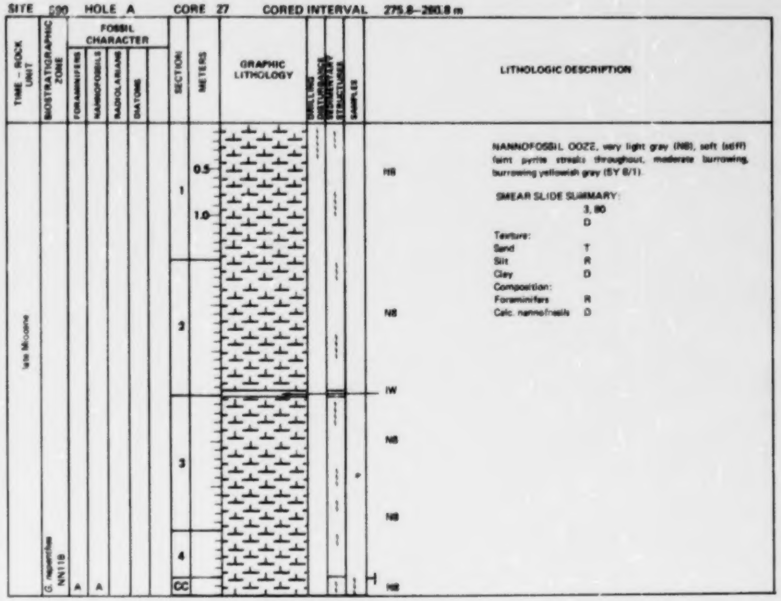
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed and faint pyrite streaks throughout, occasional silicified burrows[1]. Burrow mottling yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY

	2, 76	6, 76
	D	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 27 CORED INTERVAL 275.8–280.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN11B
A
A
1
2
3
4
CC
0.5
1.0
N8
N8
IW
N8
N8
N8

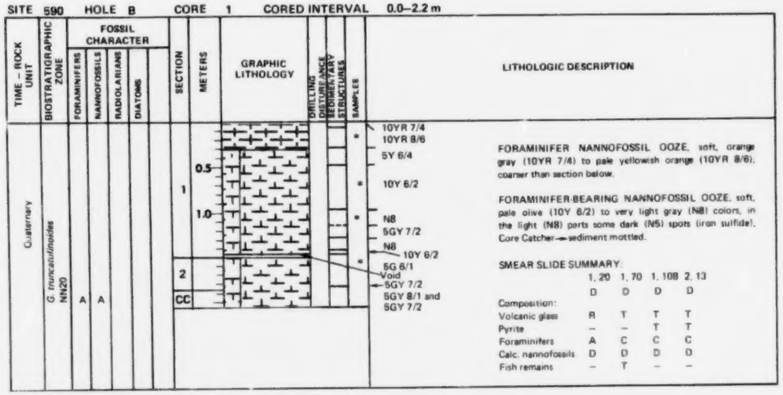
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff) faint pyrite streaks throughout, moderate burrowing, burrowing yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	3, 80
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 1 CORED INTERVAL 0.0–2.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
G. truncatulinoides
NN20
A
A
1
2
CC
0.5
1.0
10YR 7/4
10YR 8/6
5Y 6/4
10Y 6/2
N8
5GY 7/2
N8
10Y 6/2
5G 6/1
Void
5GY 7/2
5GY 8/1 and
5GY 7/2

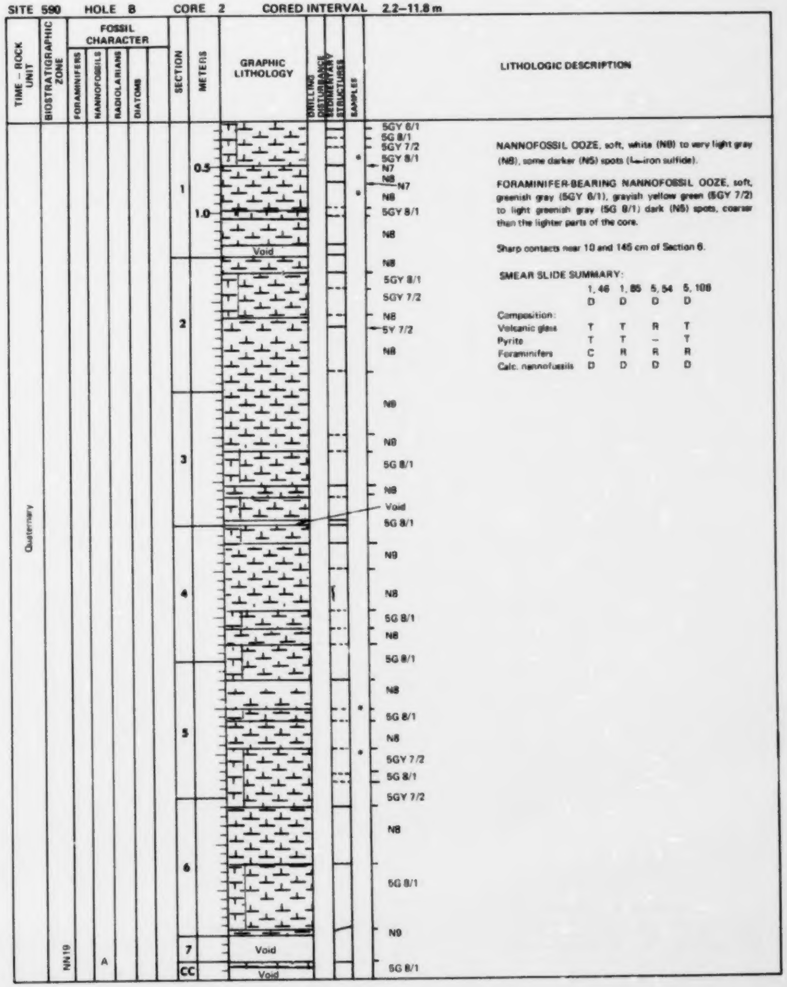
FORAMINIFER NANNOFOSSIL OOZE, soft, orange gray (10YR 7/4) to pale yellowish orange (10YR 8/6); coarser than section below.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, pale olive (10Y 6/2) to very light gray (N8) colors, in the light (N8) parts some dark (N5) spots (iron sulfide). Core Catcher→sediment mottled.

SMEAR SLIDE SUMMARY:

	1, 20	1, 70	1, 108	2, 13
	D	D	D	D
Composition:				
Volcanic glass	R	T	T	T
Pyrite	–	–	T	T
Foraminifers	A	C	C	C
Calc. nannofossils	D	D	D	D
Fish remains	–	T	–	–

SITE 590 HOLE B CORE 2 CORED INTERVAL 2.2–11.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5GY 6/1
5G 8/1
5GY 7/2
5GY 8/1
N7
N8
N7
N8
5GY 8/1
N8
N8
5GY 8/1
5GY 7/2
N8
5Y 7/2
N8
N8
N8
5G 8/1
N8
Void
5G 8/1
N9
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5GY 7/2
5G 8/1
5GY 7/2
N8
5G 8/1
N9
5G 8/1

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), some darker (N5) spots (L→iron sulfide).

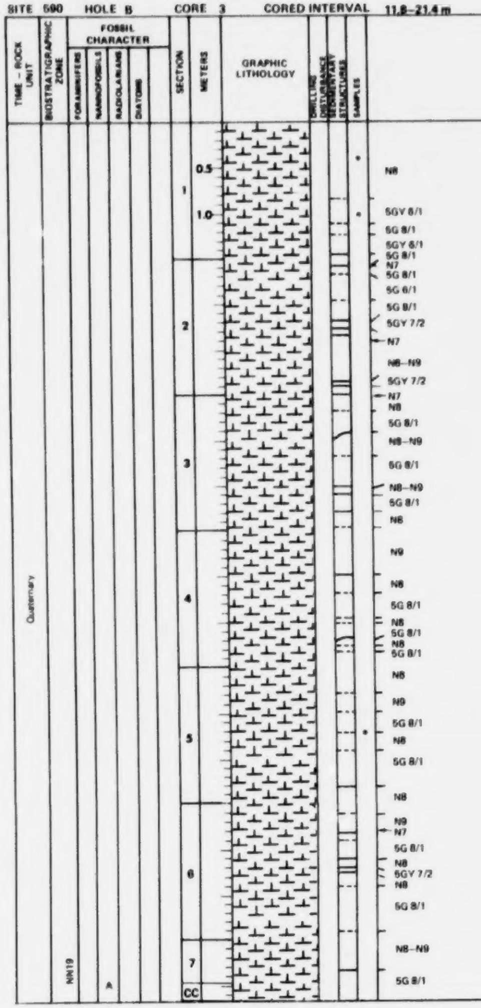
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, greenish gray (5GY 6/1), grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N5) spots, coarser than the lighter parts of the core.

Sharp contacts near 10 and 145 cm of Section 6.

SMEAR SLIDE SUMMARY:

	1, 46	1, 85	5, 54	5, 108
	D	D	D	D
Composition:				
Volcanic glass	T	T	R	T
Pyrite	T	T	–	T
Foraminifers	C	R	R	R
Calc. nannofossils	D	D	D	D

SITE 590 HOLE B CORE 3 CORED INTERVAL 11.8–21.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 8/1
5G 8/1
5GY 6/1
5G 8/1
N7
5G 8/1
5G 6/1
5G 8/1
5GY 7/2
N7
N8–N9
5GY 7/2
N7
N8
5G 8/1
N8–N9
5G 8/1
N8–N9
5G 8/1
N8
N9
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
N9
5G 8/1
N8
5G 8/1
N8
N9
N7
5G 8/1
N8
5GY 7/2
N8
5G 8/1
N8–N9
5G 8/1

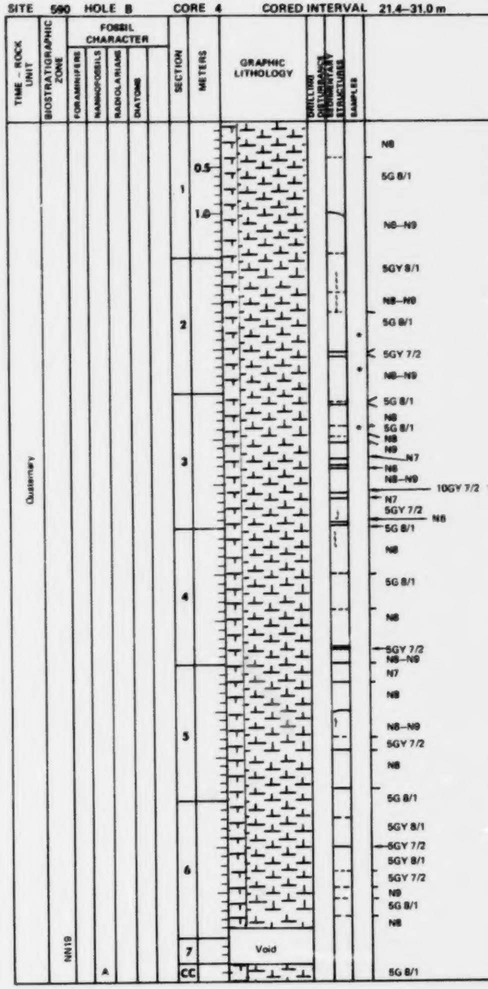
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to greenish gray (5GY 6/1), dark (N5–N4) spots and streaks throughout the entire core (↳—iron-sulfide).

SMEAR SLIDE SUMMARY:

	1, 40 D	1, 98 D	5, 75 M
Composition:			
Volcanic glass	T	T	–
Pyrite	–	–	A
Foraminifers	R	R	–
Calc. nannofossils	D	D	D
Sponge spicules	–	T	–

SITE 590 HOLE B CORE 4 CORED INTERVAL 21.4–31.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
5G 8/1
N8–N9
5GY 8/1
N8–N9
5G 8/1
5GY 7/2
N8–N9
5G 8/1
N8
5G 8/1
N8
N9
N7
N8
N8–N9
10GY 7/2 —— ash layer
N7
5GY 7/2
N8
5G 8/1
N8
5G 8/1
N8
5GY 7/2
N8–N9
N7
N8
N8–N9
5GY 7/2
N8
5G 8/1
5GY 8/1
5GY 7/2
5GY 8/1
5GY 7/2
N9
5G 8/1
N8
5G 8/1

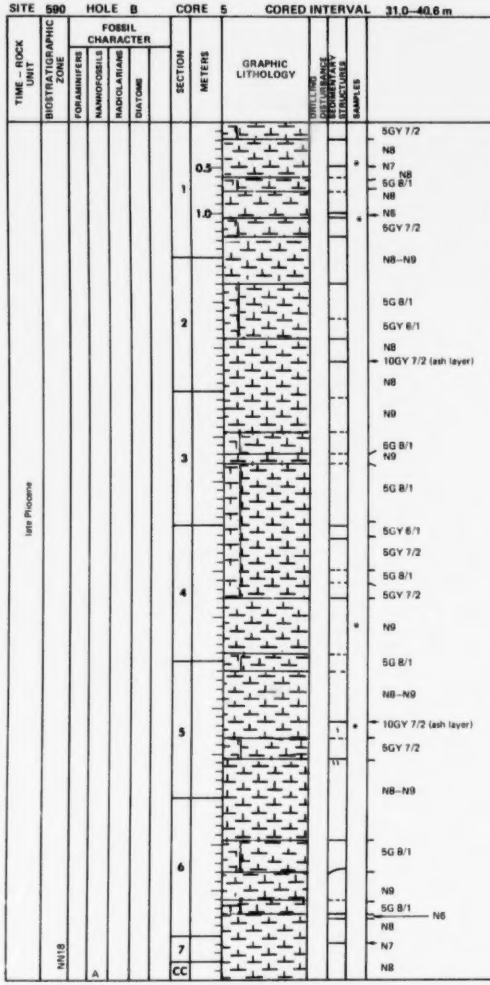
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to light greenish gray (5G 8/1), sharp contacts near 100 cm (Section 1) and 110 cm (Section 2), dark (N5) spots and streaks throughout the entire core.

SMEAR SLIDE SUMMARY:

	2, 84 D	2, 126 D	3, 40 D
Composition:			
Quartz	–	T	–
Feldspar	–	T	–
Volcanic glass	T	T	T
Pyrite	T	T	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Fish remains	–	–	T

SITE 590 HOLE B CORE 5 CORED INTERVAL 31.0–40.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN18
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 7/2
N8
N7
N8
5G 8/1
N8
N6
5GY 7/2
N8–N9
5G 8/1
5GY 6/1
N8
10GY 7/2 (ash layer)
N8
N9
5G 8/1
N9
5G 8/1
5GY 6/1
5GY 7/2
5G 8/1
5GY 7/2
N9
5G 8/1
N8–N9
10GY 7/2 (ash layer)
5GY 7/2
N8–N9
5G 8/1
N9
5G 8/1
N6
N8
N7
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5–N4) spots and streaks (iron sulfide).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, greenish yellow green (5GY 7/2) to light greenish gray (5G 8/1), dark spots and streaks throughout the entire core (iron sulfide), coarser than the whitish parts.

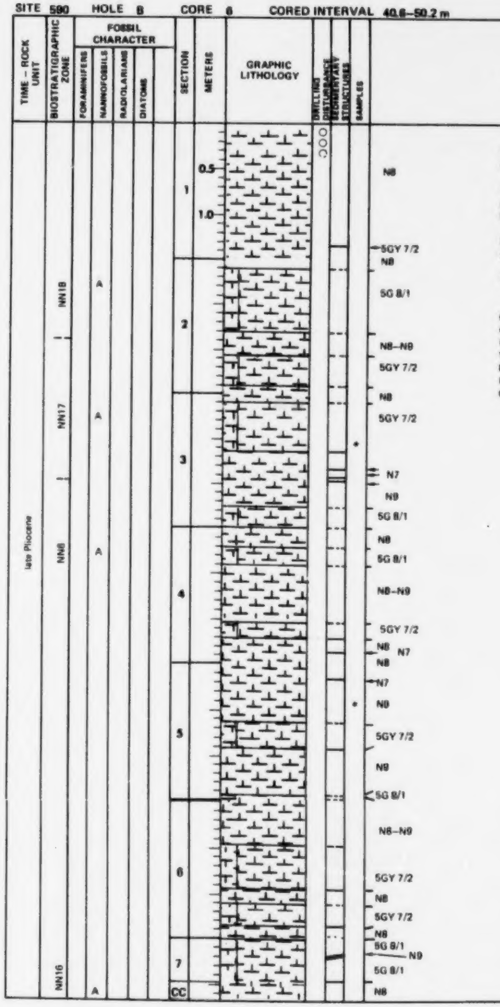
Some bioturbation (*Planolites*).

Sharp contacts near 20 and 123 cm in Section 1.

SMEAR SLIDE SUMMARY:

	1, 53	1, 115	5, 64	4, 109
	D	D	M	D
Composition:				
Volcanic glass	T	T	C	T
Pyrite	–	–	–	T
Foraminifers	R	C	C	R
Calc. nannofossils	D	D	A	D
Sponge spicules	–	–	T	–

SITE 590 HOLE B CORE 6 CORED INTERVAL 40.6–50.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN18
NN17
NN8
NN16
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 7/2
N8
5G 8/1
N8–N9
5GY 7/2
N8
5GY 7/2
N7
N9
5G 8/1
N8
5G 8/1
N8–N9
5GY 7/2
N8
N7
N8
N7
N9
5GY 7/2
N9
5G 8/1
N8–N9
5GY 7/2
N8
5GY 7/2
N8
5G 8/1
N9
5G 8/1
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5) spots and streaks.

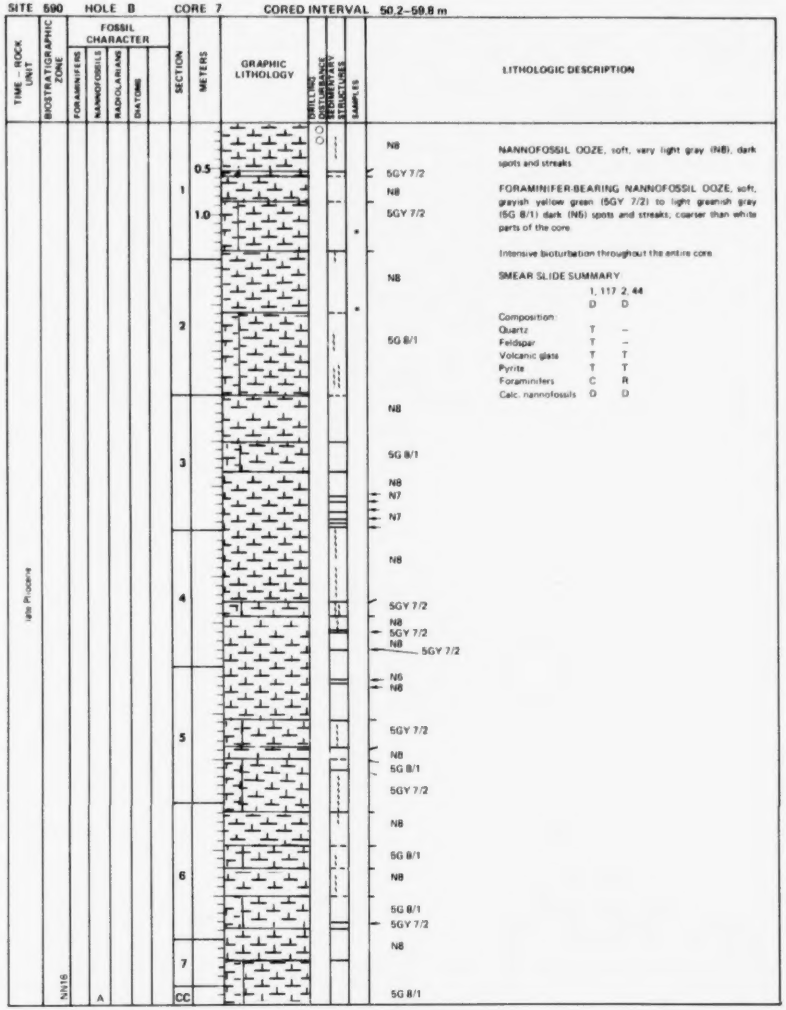
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N5) spots and streaks, coarser than white parts.

Sharp contacts near 140 cm (Section 2), 68 cm (Section 3), and 94 and 135 cm (Section 6).

SMEAR SLIDE SUMMARY:

	3, 50	5, 40
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 7 CORED INTERVAL 50.2–59.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN16
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 7/2
N8
5GY 7/2
N8
5G 8/1
N8
5G 8/1
N8
N7
N7
N8
5GY 7/2
N8
5GY 7/2
N8
5GY 7/2
N6
N8
5GY 7/2
N8
5G 8/1
5GY 7/2
N8
5G 8/1
N8
5G 8/1
5GY 7/2
N8
5G 8/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), dark spots and streaks.

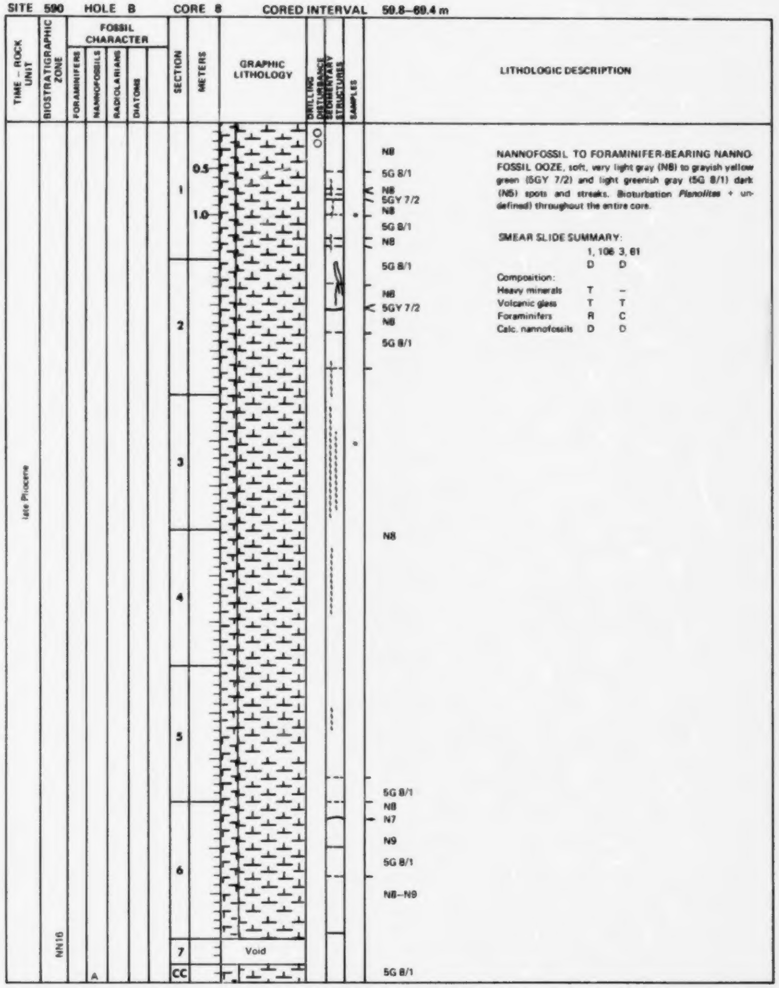
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N6) spots and streaks; coarser than white parts of the core.

Intensive bioturbation throughout the entire core.

SMEAR SLIDE SUMMARY:

	1, 117	2, 44
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 8 CORED INTERVAL 59.8–69.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN16
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
5G 8/1
N8
5GY 7/2
N8
5G 8/1
N8
5G 8/1
N8
5GY 7/2
N8
5G 8/1
N8
5G 8/1
N8
N7
N9
5G 8/1
N8–N9
5G 8/1

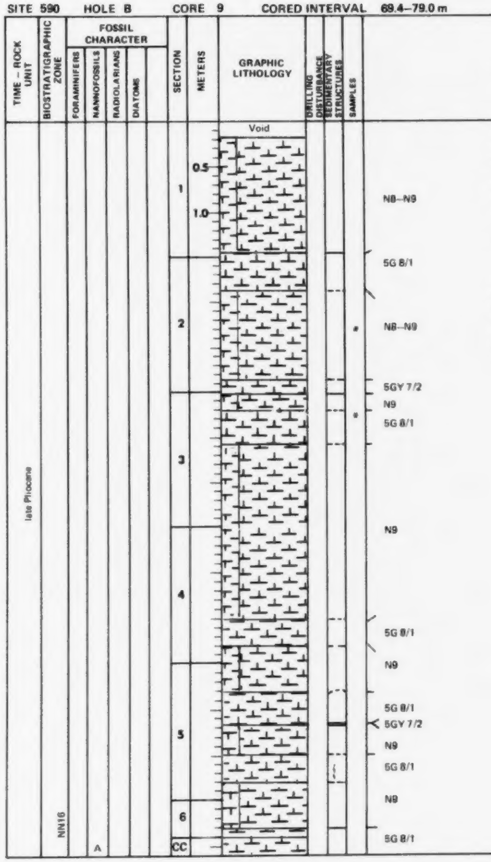
LITHOLOGIC DESCRIPTION

NANNOFOSSIL TO FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) to grayish yellow green (5GY 7/2) and light greenish gray (5G 8/1) dark (N5) spots and streaks. Bioturbation *Planolites* + undefined) throughout the entire core.

SMEAR SLIDE SUMMARY:

	1, 106	3, 61
	D	D
Composition:		
Heavy minerals	T	–
Volcanic glass	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 9 CORED INTERVAL 69.4–79.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN16
A
Void
0.5
1.0
1
2
3
4
5
6
CC
N8–N9
5G 8/1
N8–N9
5GY 7/2
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
5GY 7/2
N9
5G 8/1
N9
5G 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

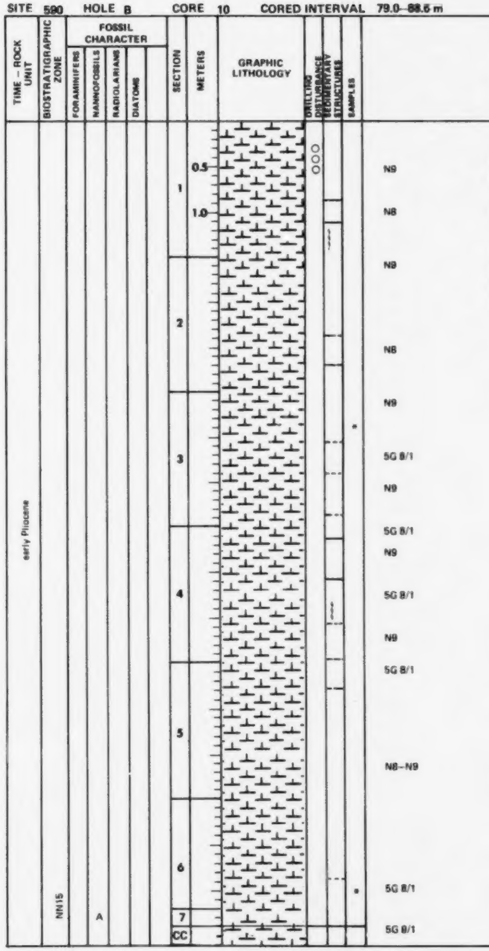
Greenish parts fewer foraminifers └→NANNOFOSSIL OOZE.

Dark (N5) spots and streaks throughout the entire core.

SMEAR SLIDE SUMMARY:

	2, 81	3, 35
	D	D
Composition:		
Heavy minerals	T	—
Volcanic glass	T	T
Pyrite	—	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 10 CORED INTERVAL 79.0–88.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
N8
N9
N8
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
N8–N9
5G 8/1
5G 8/1

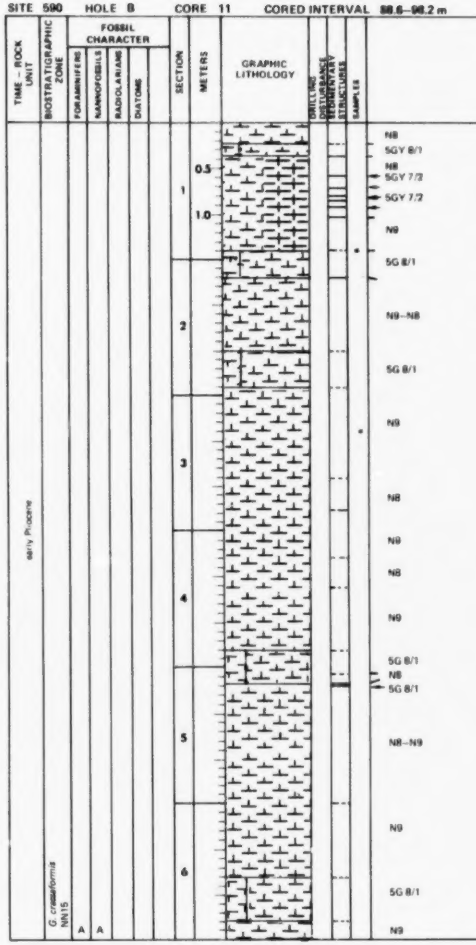
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5) spots (└→iron sulfide). Bioturbation in Sections 1 and 4.

SMEAR SLIDE SUMMARY:

	3, 36	6, 107
	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	—
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 11 CORED INTERVAL 88.6–98.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
1
2
3
4
5
6
0.5
1.0
N8
5GY 8/1
N8
5GY 7/2
5GY 7/2
N9
5G 8/1
N9–N8
5G 8/1
N9
N8
N9
N8
N9
5G 8/1
N8
5G 8/1
N8–N9
N9
5G 8/1
N9

LITHOLOGIC DESCRIPTION

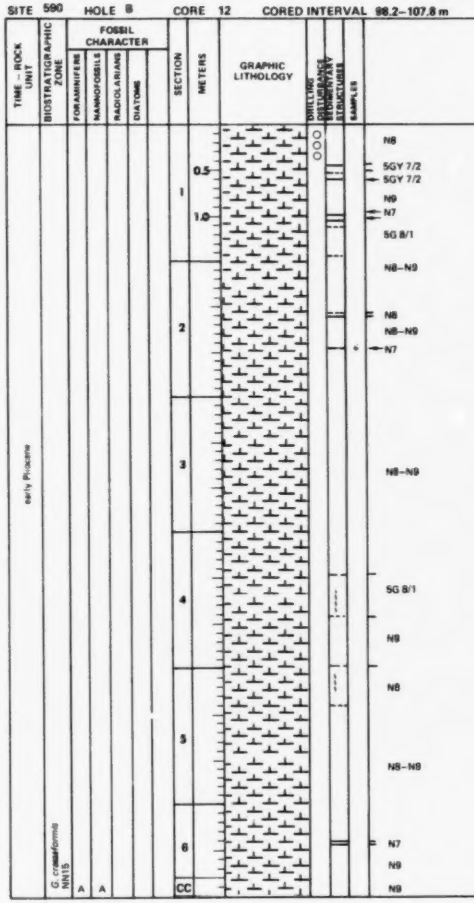
NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark spots and streaks.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark spots and streaks, coarser than the white parts of the core.

SMEAR SLIDE SUMMARY:

	1, 146	3, 37
	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 12 CORED INTERVAL 98.2–107.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5GY 7/2
5GY 7/2
N9
N7
5G 8/1
N8–N9
N8
N8–N9
N7
N8–N9
5G 8/1
N9
N8
N8–N9
N7
N9
N9

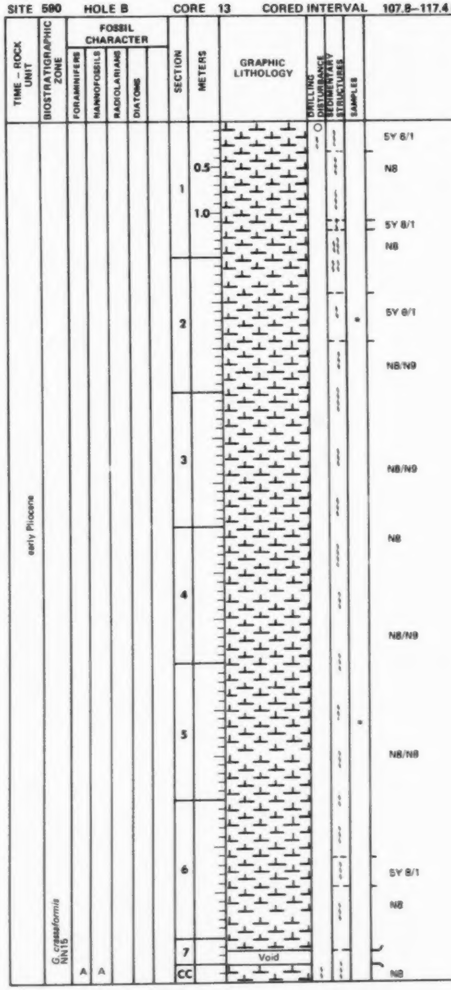
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to grayish yellow green (5GY 7/2). Some dark spots and streaks (←iron sulfide). Gradational color changes.

SMEAR SLIDE SUMMARY:

	2, 96
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 13 CORED INTERVAL 107.8–117.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
N8/N9
N8/N9
N8
N8/N9
N8/N8
5Y 8/1
N8
N8

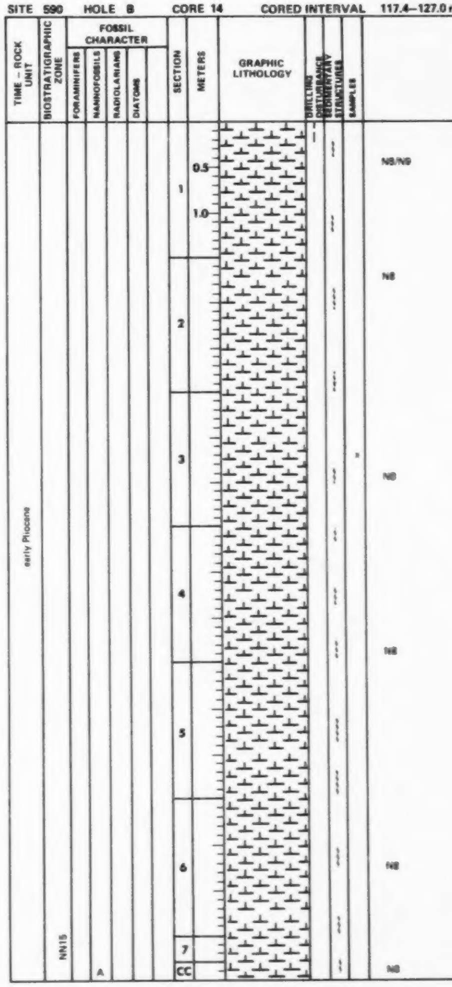
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), with layers of light olive gray (5Y 8/1), moderately burrowed, burrows yellowish gray (5Y 8/1), occasional pyrite blebs and concretions, faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	2, 73	5, 73
	D	D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 14 CORED INTERVAL 117.4–127.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8/N9
N8
N8
N8
N8
N8

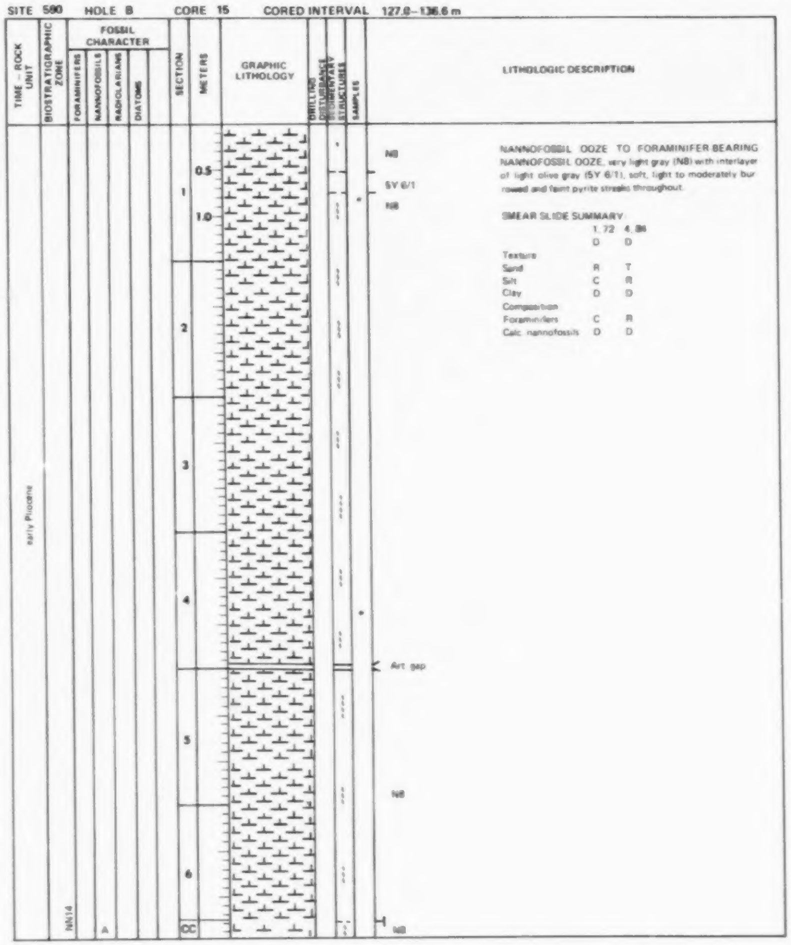
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), light to moderately burrowed, faint pyrite streaks throughout, occasional pyrite blebs.

SMEAR SLIDE SUMMARY:

	3, 69
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 15 CORED INTERVAL 127.0–136.6 m

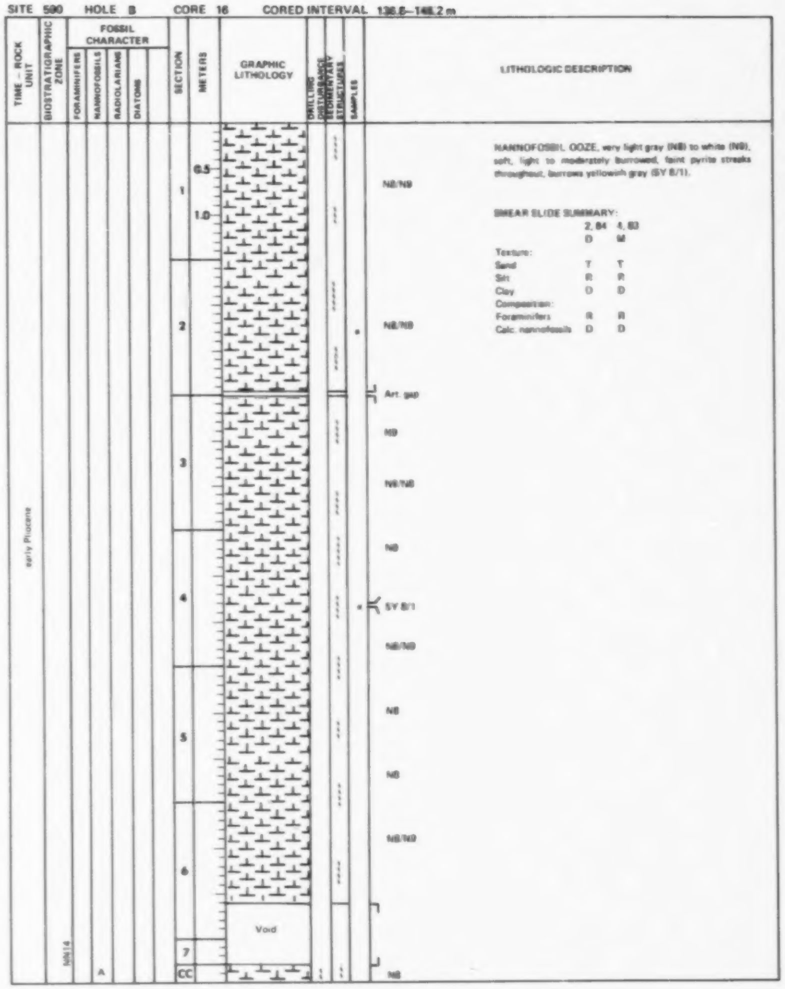

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN14
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5Y 6/1
N8
Art. gap
N8
N8

NANNOFOSSIL OOZE TO FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (N8) with interlayer of light olive gray (5Y 6/1), soft, light to moderately burrowed and faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY

	1, 72	4, 84
	D	D
Texture		
Sand	R	T
Silt	C	R
Clay	D	D
Composition		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 16 CORED INTERVAL 136.6–146.2 m

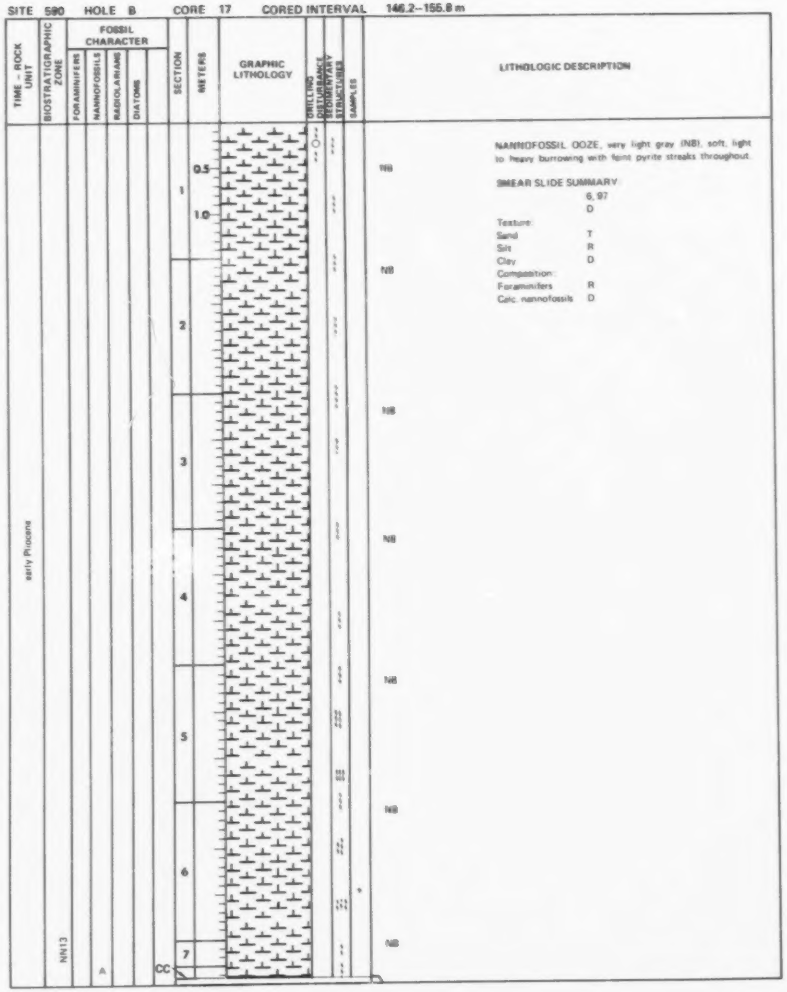

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN14
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8/N9
N8/N9
Art. gap
N9
N8/N8
N8
5Y 8/1
N8/N9
N8
N8
N8/N9
N8

NANNOFOSSIL OOZE, very light gray (N8) to white (N9), soft, light to moderately burrowed, faint pyrite streaks throughout, burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 84	4, 83
	D	M
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 17 CORED INTERVAL 146.2–155.8 m

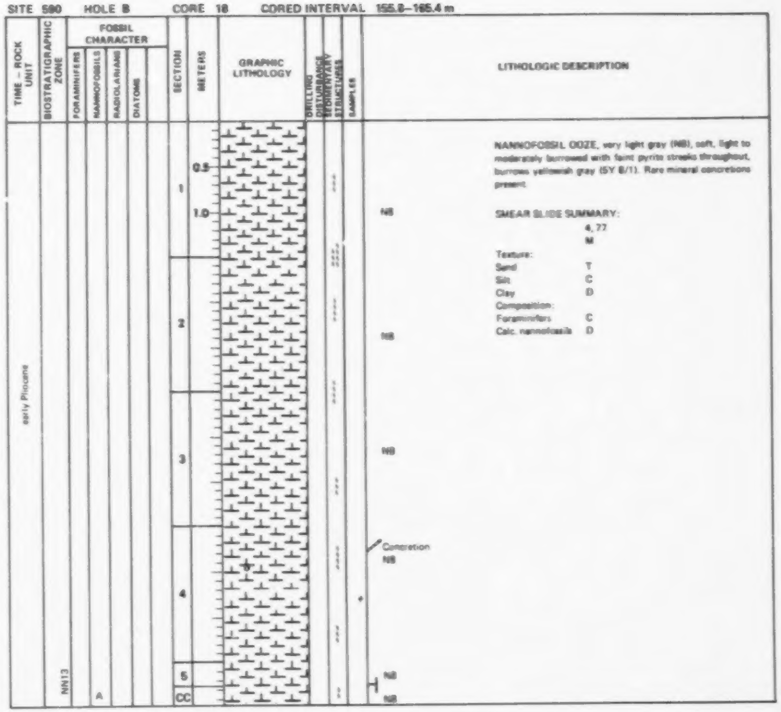

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN13
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
N8
N8
N8
N8
N8
N8

NANNOFOSSIL OOZE, very light gray (N8), soft, light to heavy burrowing with faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY

	6, 97
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 18 CORED INTERVAL 155.8–165.4 m

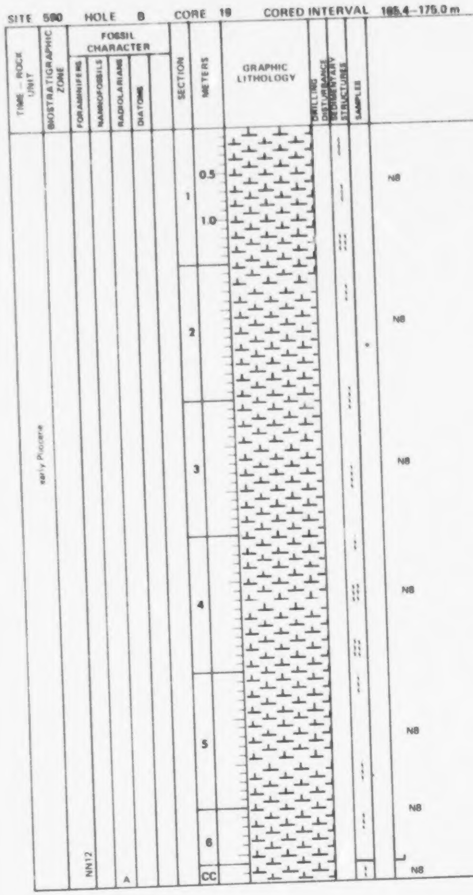

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN13
A
0.5
1.0
1
2
3
4
5
CC
N8
N8
N8
Concretion
N8
N8
N8

NANNOFOSSIL OOZE, very light gray (N8), soft, light to moderately burrowed with faint pyrite streaks throughout, burrows yellowish gray (5Y 8/1). Rare mineral concretions present.

SMEAR SLIDE SUMMARY:

	4, 77
	M
Texture:	
Sand	T
Silt	C
Clay	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 590 HOLE B CORE 19 CORED INTERVAL 165.4–175.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN12
A
0.5
1.0
1
2
3
4
5
6
CC
N8
N8
N8
N8
N8
N8
N8

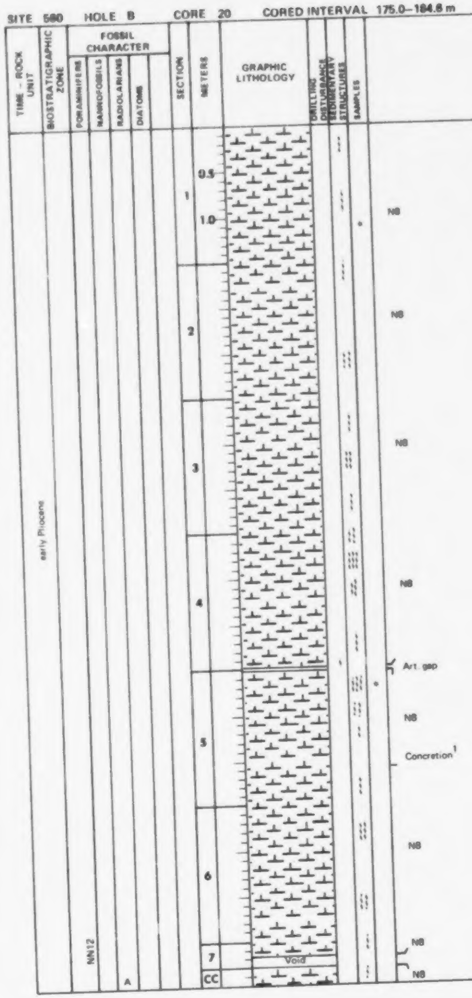
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed with faint pyrite streaks and halos throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY

	2, 92
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 20 CORED INTERVAL 175.0–184.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN12
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
N8
N8
N8
Art. gap
N8
Concretion[1]
N8
N8
N8

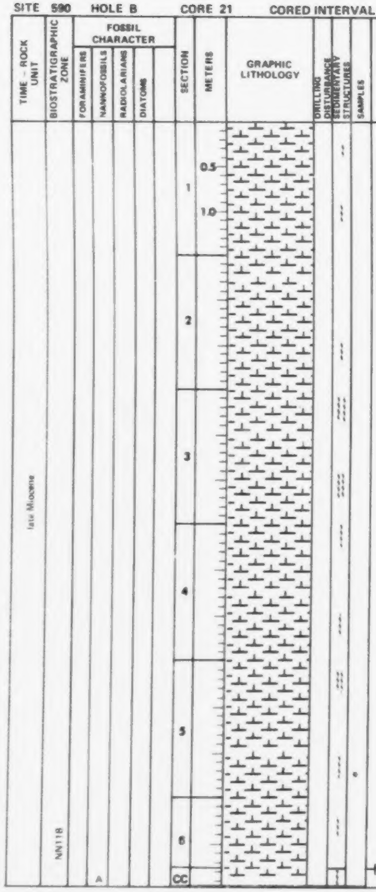
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, light to heavily mottled yellowish gray (5Y 8/1) by burrowing, faint pyrite streaks throughout. Mineralized burrow[1] at 5, 110 cm.

SMEAR SLIDE SUMMARY:

	1, 115	5, 17
	D	M
Texture:		
Sand	T	T
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 21 CORED INTERVAL 184.6–194.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
0.5
1.0
1
2
3
4
5
6
CC
NB
NB
NB
NB
NB
NB
NB

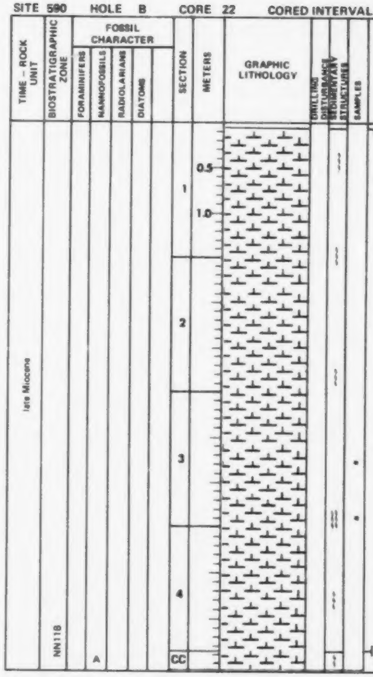
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed and faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	5, 125
	M
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 590 HOLE B CORE 22 CORED INTERVAL 194.2–203.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
0.5
1.0
1
2
3
4
CC
Art. gap
N8
N8
N8
N8
N8

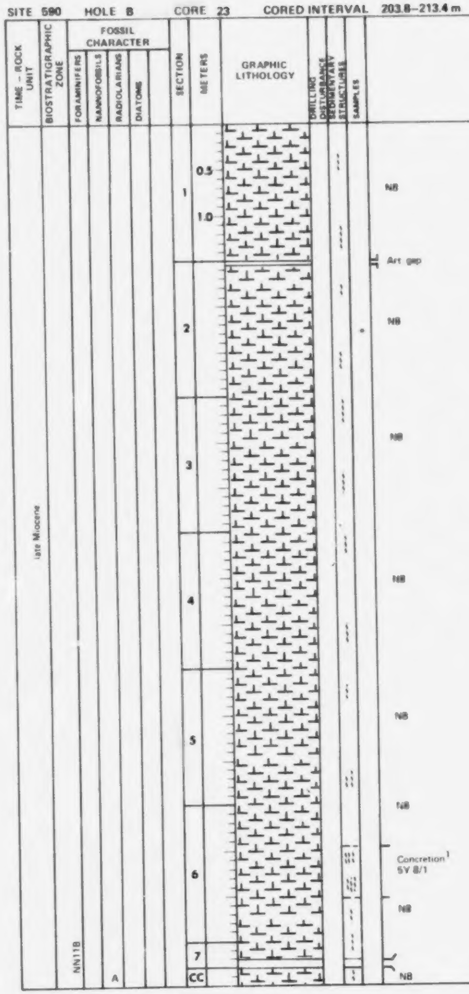
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderate burrowing with pyrite streaks throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	3, 79	3, 145
	D	M
Texture:		
Sand	T	C
Silt	R	A
Clay	D	A
Composition:		
Pyrite	T	–
Foraminifers	R	A
Calc. nannofossils	D	A
Sponge spicules	T	–
Volcanic glass	T	–
Clay minerals	T	–

SITE 590 HOLE B CORE 23 CORED INTERVAL 203.8–213.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
Art. gap
N8
N8
N8
N8
N8
Concretion 1
5Y 8/1
N8
N8

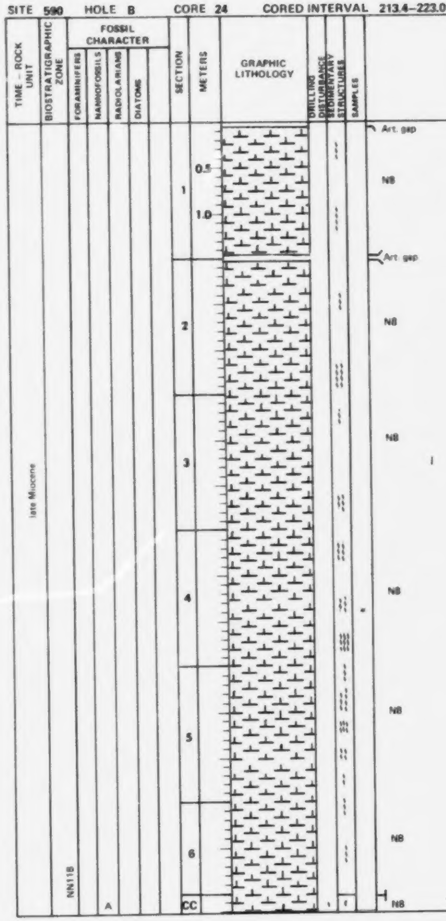
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8) with heavily burrowed portions yellowish gray (5Y 8/1), soft, moderate to heavily burrowed, large concretion present [1]

SMEAR SLIDE SUMMARY:

	2, 80	6, 72
	D	M
Texture:		
Sand	T	C
Silt	R	C
Clay	C	A
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	A
Clay minerals	T	—
Pyrite	T	—

SITE 590 HOLE B CORE 24 CORED INTERVAL 213.4–223.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
1
2
3
4
5
6
CC
0.5
1.0
Art. gap
N8
Art. gap
N8
N8
N8
N8
N8
N8

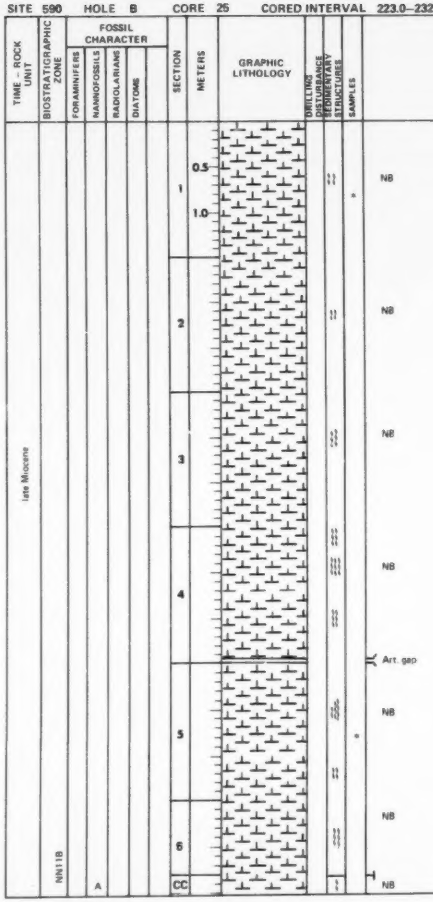
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed with light streaks of pyrite. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	4, 80
	D
Texture:	
Sand	R
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D
Feldspar	T
Volcanic glass	T
Clay minerals	T
Pyrite	T

SITE 590 HOLE B CORE 25 CORED INTERVAL 223.0–232.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
0.5
1.0
1
2
3
4
5
6
CC
N8
N8
N8
N8
Art. gap
N8
N8
N8

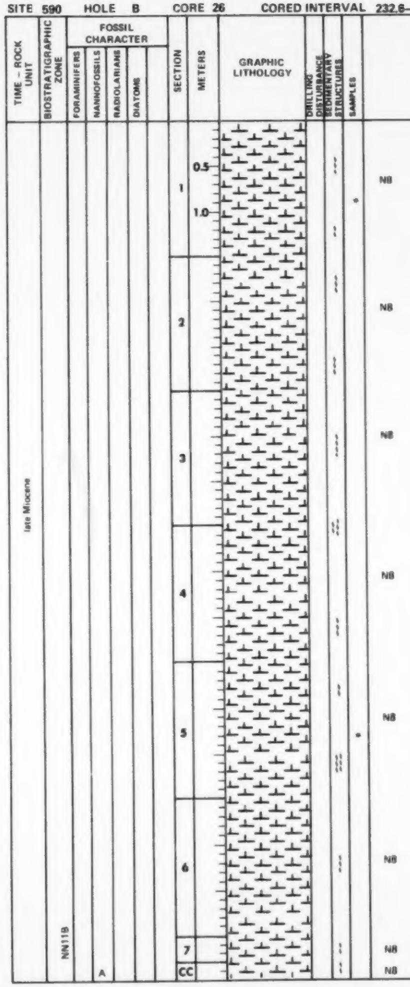
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderate to heavily burrowed, burrows yellowish gray (5Y 8/1), pyrite streaks and halos medium light gray (N6).

SMEAR SLIDE SUMMARY:

	1, 79 D	5, 77 D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D
Quartz	T	–
Volcanic glass	T	T
Clay minerals	T	T
Pyrite	–	T

SITE 590 HOLE B CORE 26 CORED INTERVAL 232.6–242.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
N8
N8
N8
N8
N8
N8
N8

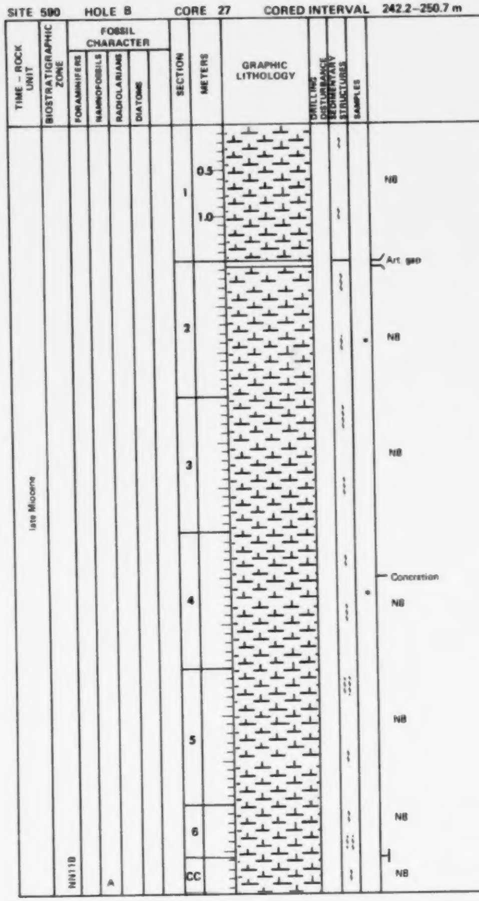
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed throughout, burrows yellowish gray (5Y 8/1), faint pyrite streaks medium gray (N6) frequent.

SMEAR SLIDE SUMMARY:

	1, 83 D	5, 86 D
Texture:		
Sand	R	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D
Volcanic glass	T	T
Clay minerals	R	T
Pyrite	T	T
Feldspar	–	T

SITE 590 HOLE B CORE 27 CORED INTERVAL 242.2–250.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
1
2
3
4
5
6
CC
0.5
1.0
N8
Art. gap
N8
N8
Concretion
N8
N8
N8
N8

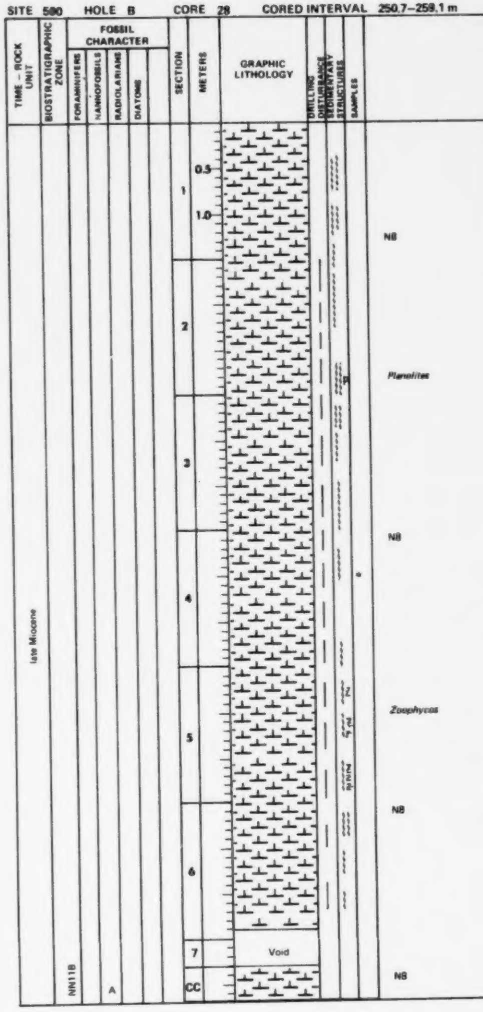
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed, burrows yellowish gray (5Y 8/1), faint pyrite streaks medium gray (N8) throughout.

SMEAR SLIDE SUMMARY:

	2, 85 D	4, 64 M
Texture:		
Sand	T	C
Silt	R	C
Clay	D	A
Composition:		
Foraminifers	R	A
Calc. nannofossils	D	A
Sponge spicules	T	–
Volcanic glass	T	–
Clay minerals	T	–
Zeolites	T	–

SITE 590 HOLE B CORE 28 CORED INTERVAL 250.7–259.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
Planolites
N8
Zoophycos
N8
N8

LITHOLOGIC DESCRIPTION

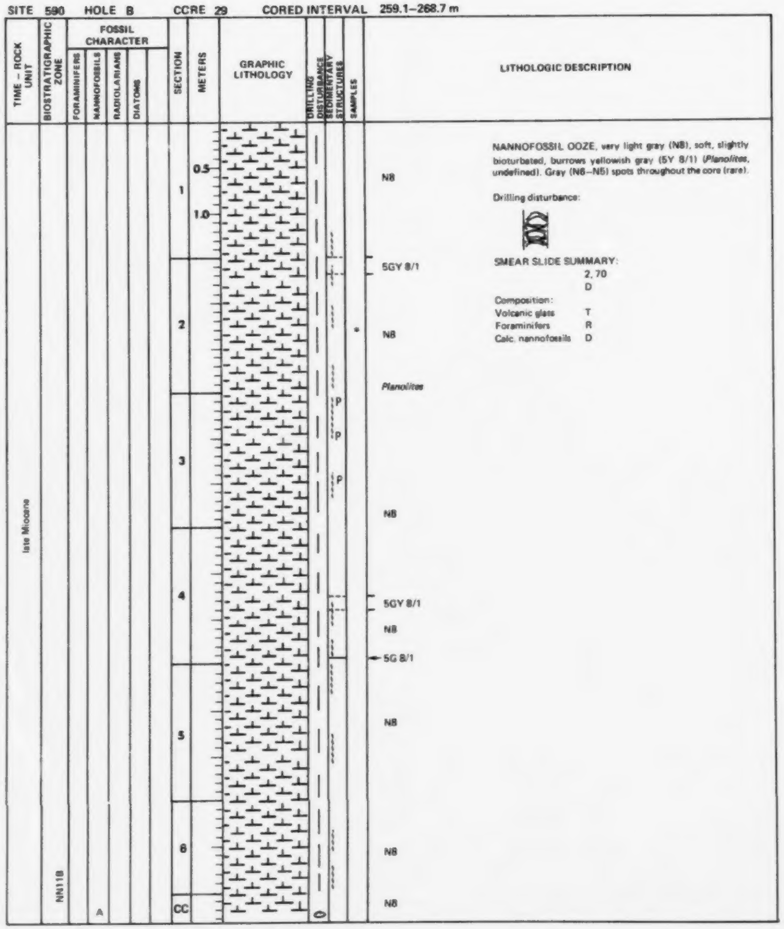
NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed, burrows (*Planolites*, *Zoophycos*) grayish yellow green (5GY 7/2) to yellowish gray (5Y 8/1), gray (N6–N5) streaks rare.

Drilling disturbance:

SMEAR SLIDE SUMMARY:

	4, 54 D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CCRE 29 CORED INTERVAL 259.1–268.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN11B
A
1
2
3
4
5
6
CC
0.5
1.0
P
P
P
N8
5GY 8/1
N8
Planolites
N8
5GY 8/1
N8
5G 8/1
N8
N8
N8

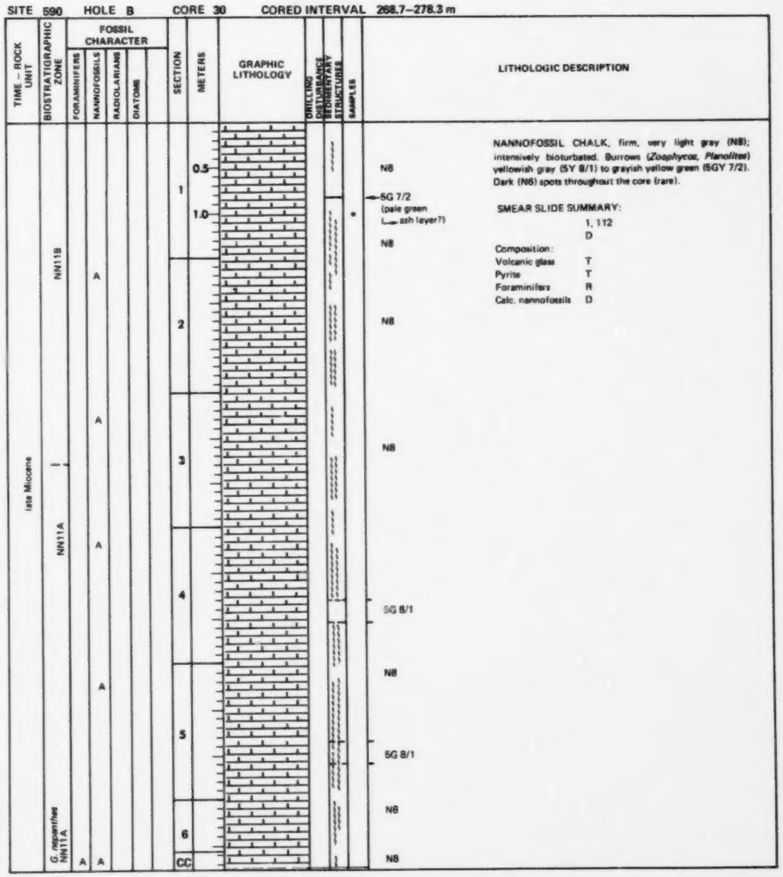
NANNOFOSSIL OOZE, very light gray (N8), soft, slightly bioturbated, burrows yellowish gray (5Y 8/1) (*Planolites*, undefined). Gray (N6–N5) spots throughout the core (rare).

Drilling disturbance:

SMEAR SLIDE SUMMARY:

	2, 70 D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 30 CORED INTERVAL 268.7–278.3 m

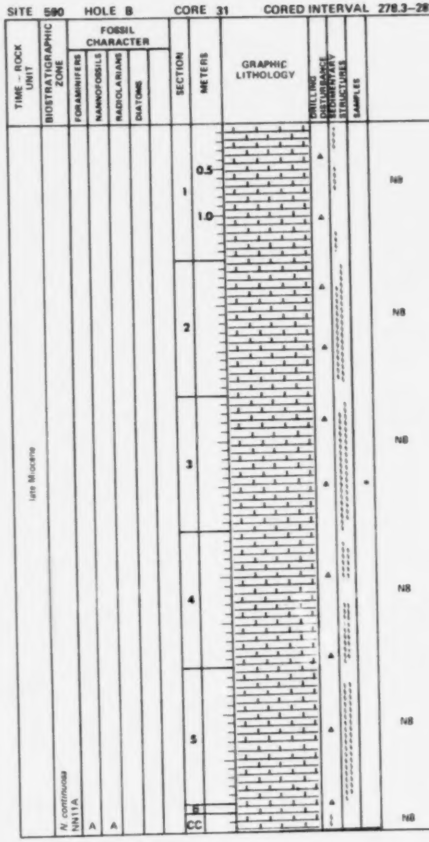

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN11B
NN11A
G. nepenthes NN11A
A
A
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5G 7/2 (pale green ash layer?)
N8
N8
N8
5G 8/1
N8
5G 8/1
N8
N8

NANNOFOSSIL CHALK, firm, very light gray (N8); intensively bioturbated. Burrows (*Zoophycos, Planolites*) yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2). Dark (N6) spots throughout the core (rare).

SMEAR SLIDE SUMMARY:

	1, 112 D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 31 CORED INTERVAL 278.3–287.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
N8
N8
N8
N8
N8

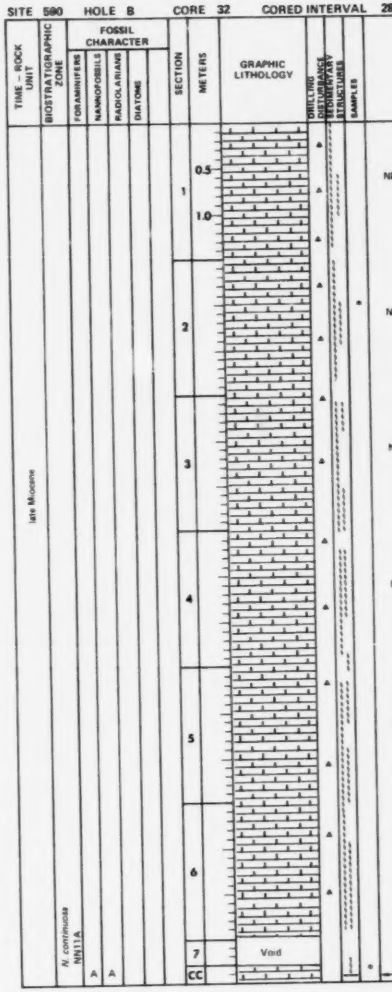
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8), moderately to intensively bioturbated. Burrow (*Zoophycos*, *Planolites*) yellowish gray (5Y 8/1) and light gray (N7). Dark (N6–N7) spots throughout the entire core (rare).

SMEAR SLIDE SUMMARY:

	3, 102
Composition:	D
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 590 HOLE B CORE 32 CORED INTERVAL 287.9–297.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
N8
N8
N8
N8
N8
5G 7/2
ash layer(?)

LITHOLOGIC DESCRIPTION

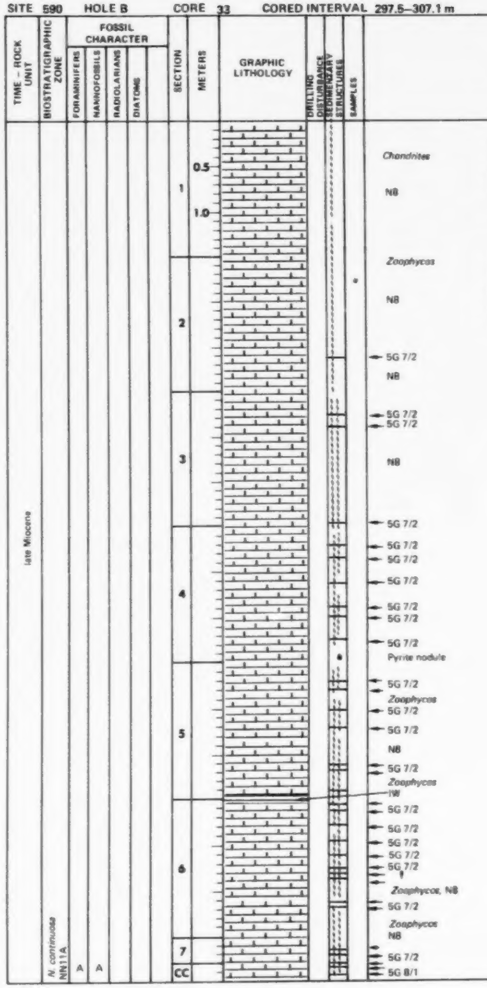
NANNOFOSSIL CHALK, firm, very light gray (N8), intensively bioturbated burrows (*Zoophycos*, *Planolites*) yellow gray (5Y 8/1) and light gray (N7). Dark (N6–N7)

SMEAR SLIDE SUMMARY:

	2, 46 D	CC[1] M
Composition:		
Volcanic glass	T	R
Pyrite	T	C
Foraminifers	R	–
Calc. nannofossils	D	–
Diatoms	–	C
Radiolarians(?)	–	C
Sponge spicules	–	T
Silicoflagellates	–	T

[1] Insol. residue

SITE 590 HOLE B CORE 33 CORED INTERVAL 297.5–307.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Chondrites
NB
Zoophycos
NB
5G 7/2
NB
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
Pyrite nodule
5G 7/2
Zoophycos
5G 7/2
5G 7/2
NB
5G 7/2
Zoophycos
IW
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
Zoophycos, NB
5G 7/2
Zoophycos
NB
5G 7/2
5G 8/1

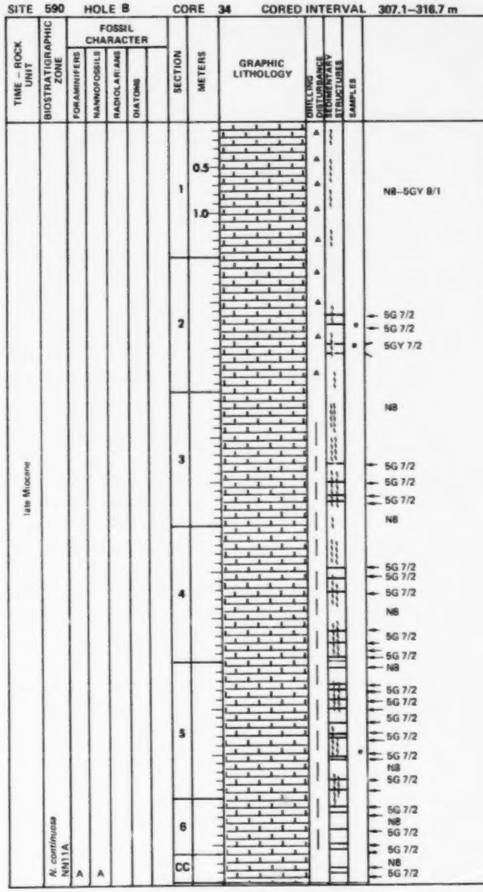
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8), moderately to intensively bioturbated. Burrows (*Zoophycos, Planolites, Chondrites*) yellowish gray (5Y 8/1) to light gray (N7). Increased bioturbation Sections 3–7, fine pale green (5G 7/2) layers └→ash layers(?).

SMEAR SLIDE SUMMARY:

	2, 31
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 590 HOLE B CORE 34 CORED INTERVAL 307.1–316.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
CC
0.5
1.0
NB–5GY 8/1
5G 7/2
5G 7/2
5GY 7/2
NB
5G 7/2
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
NB
5G 7/2
5G 7/2
NB
5G 7/2

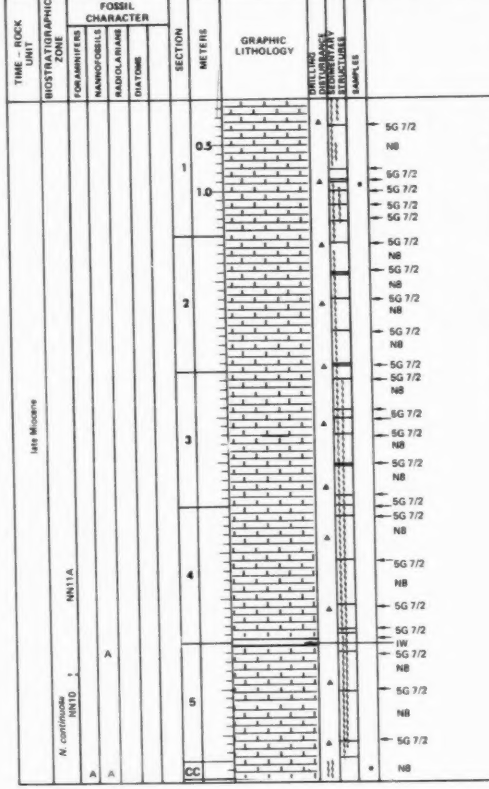
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5GY 8/1); moderately to heavily bioturbated. Burrows (*Zoophycos, Planolites*) yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2). Dark spots throughout the core. Pale green (5G 7/2) thin layers (└→ash layer?).

SMEAR SLIDE SUMMARY:

	2, 70	2, 112	5, 102
	D	M	M
Composition:			
Volcanic glass	T	–	–
Pyrite	T	–	–
Foraminifers	R	R	R
Calc. nannofossils	D	D	D

SITE 590 HOLE B CORE 35 CORED INTERVAL 316.7–326.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11A
N. continuosa
NN10
A
A
A
1
2
3
4
5
CC
0.5
1.0
5G 7/2
N8
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
5G 7/2
N8
5G 7/2
5G 7/2
N8
5G 7/2
N8
5G 7/2
5G 7/2
N8
5G 7/2
N8
5G 7/2
5G 7/2
IW
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8), intensively bioturbated (*Zoophycos, Planolites, Chondrites*) yellow gray (5Y 8/1). Dark (N6–N7) spots. Thin pale green (5G 7/2) laminae └→ ash layers(?).

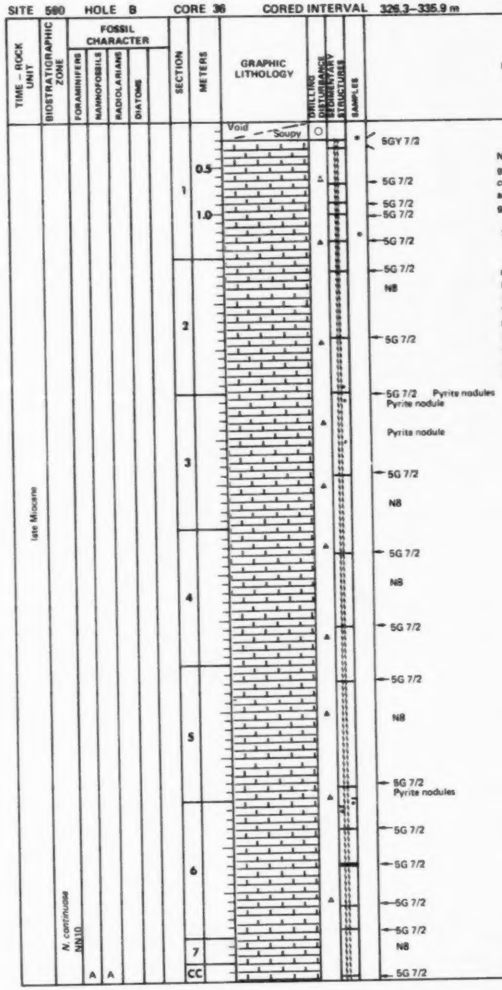
Microfault near 75 cm Section 3.

SMEAR SLIDE SUMMARY:

	1, 100	CC[1]
	D	M
Composition:		
Quartz	T	–
Feldspar	T	T
Volcanic glass	T	T
Pyrite	–	C
Foraminifers	R	–
Calc. nannofossils	D	–
Diatoms	–	C
Radiolarians	T	C
Sponge spicules	–	R
Unident.	–	A

[1] Insol. residue

SITE 590 HOLE B CORE 36 CORED INTERVAL 326.3–335.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN10
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
Soupy
5GY 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N8
5G 7/2
5G 7/2 Pyrite nodules
Pyrite nodule
Pyrite nodule
5G 7/2
N8
5G 7/2
N8
5G 7/2
5G 7/2
N8
5G 7/2
Pyrite nodules
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N8
5G 7/2

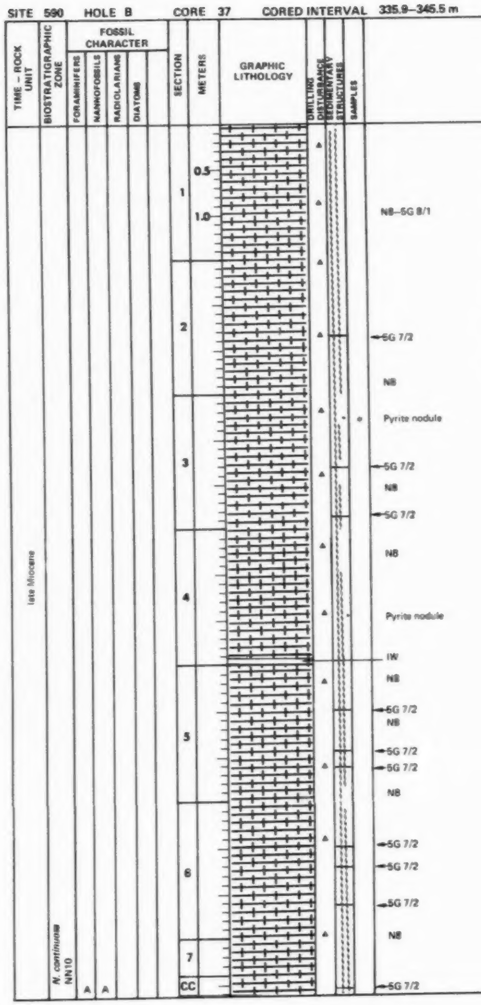
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5GY 8/1), intensively bioturbated (*Zoophycos, Planolites*). Burrows grayish yellow green (5GY 7/2) and yellowish gray (5Y 8/1). Dark (N6) spots. Thin pale green (5G 7/2) layers └→ ash layers?.

SMEAR SLIDE SUMMARY:

	1, 22	1, 124
	M	D
Composition:		
Feldspar	T	–
Clay	C	–
Volcanic glass	T	T
Pyrite	–	T
Foraminifers	R	R
Calc. nannofossils	D	D
Radiolarians	T	–
Unident.		C
(degrad. ash?)	C	–

SITE 590 HOLE B CORE 37 CORED INTERVAL 335.9–345.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN10
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8–5G 8/1
5G 7/2
N8
Pyrite nodule
5G 7/2
N8
5G 7/2
N8
Pyrite nodule
IW
N8
5G 7/2
N8
5G 7/2
5G 7/2
N8
5G 7/2
5G 7/2
5G 7/2
N8
5G 7/2

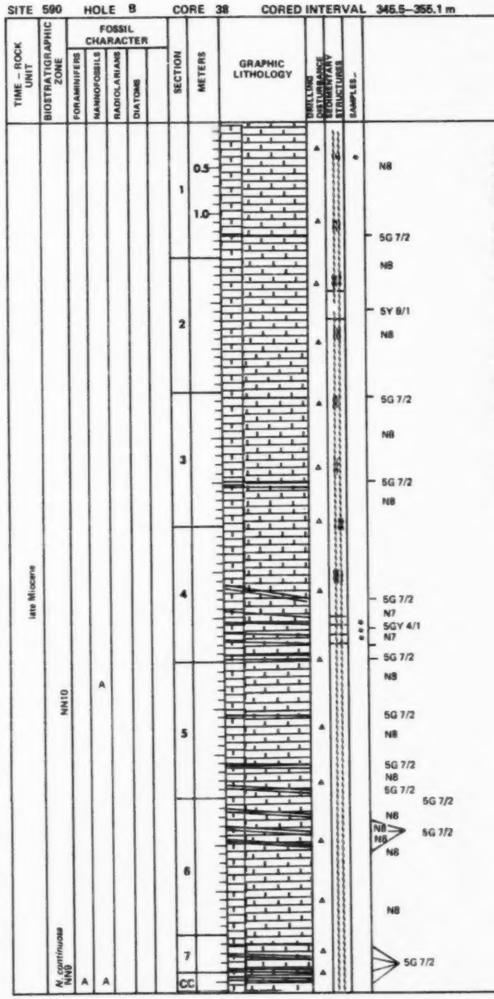
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1); intensively bioturbated (*Planolites, Zoophycos, Chondrites*). Burrows yellowish gray (5Y 8/1), grayish yellow green (5GY 7/2), and light gray (N7); dark spots (N6). Thin pale green (5G 7/2) laminae └→ash layers(?).

SMEAR SLIDE SUMMARY:

	3, 29 D
Composition:	
Heavy minerals	T
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	C
Calc. nannofossils	A
Radiolarians	T
Pyrite	T

SITE 590 HOLE B CORE 38 CORED INTERVAL 345.5–355.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN10
N. continuosa
NN9
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5G 7/2
N8
5Y 8/1
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N7
5GY 4/1
N7
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
5G 7/2
N8
N8
N8
5G 7/2
N8
N8
5G 7/2

LITHOLOGIC DESCRIPTION

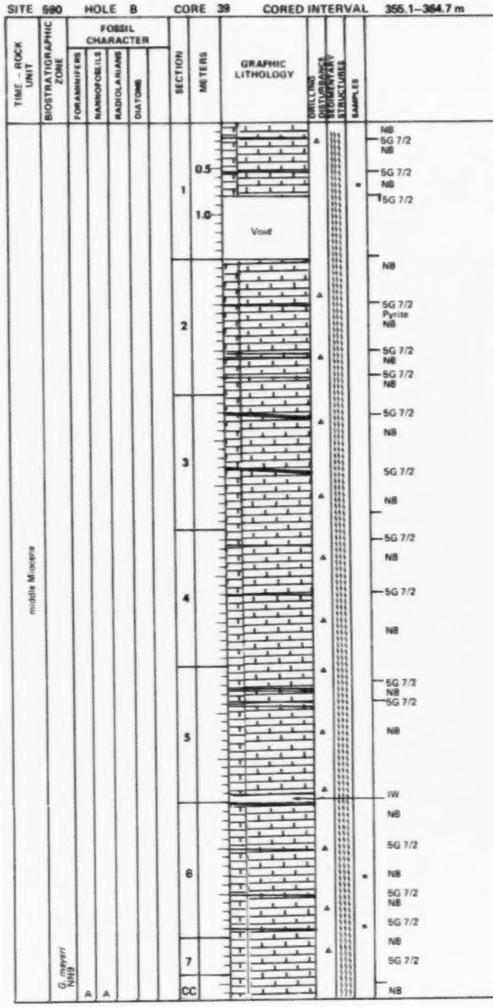
FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated with burrows yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2), light gray (N8) pyrite streaks. Pale green (5G 7/2) ash(?) layers periodically.

PYRITIFEROUS VITRIC ASH in Section 4 at 105–115 cm, dark greenish gray (5GY 4/1), VITRIC ASH FORAMINIFER NANNOFOSSIL CHALK, below to ~ 130 cm, medium light gray to light gray (N7). *Zoophycos* burrows obvious.

SMEAR SLIDE SUMMARY:

	1, 43 D	4, 112 M	4, 127 M
Texture:			
Sand	R	R	A
Silt	C	D	A
Clay	D	R	A
Composition:			
Feldspar	–	R	T
Clay minerals (incl. mica)	T	R	R
Heavy minerals	–	T	–
Volcanic glass	T	A	A
Pyrite	T	A	T
Foraminifers	C	T	A
Calc. nannofossils	D	R	A
Radiolarians	T	–	–

SITE 590 HOLE B CORE 39 CORED INTERVAL 355.1–364.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri
NN9
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
Pyrite
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
IW
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8

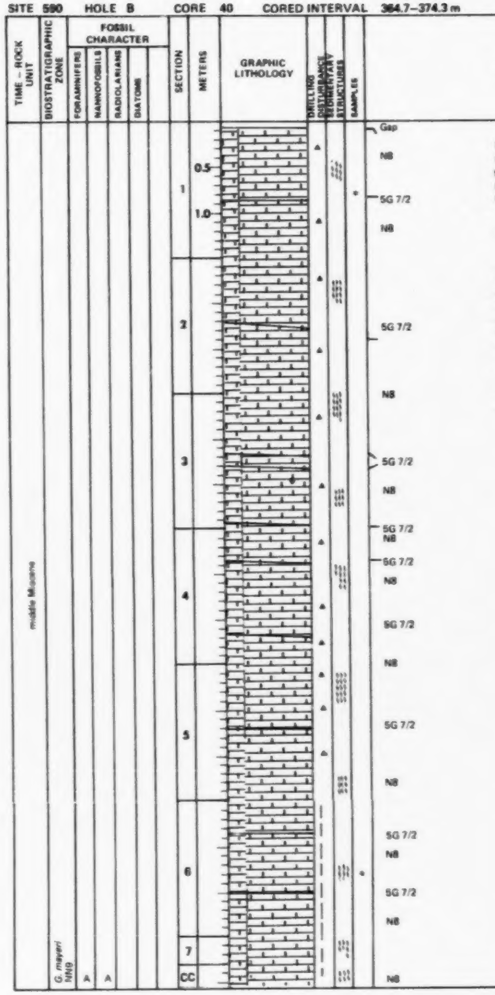
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated. Burrows yellowish gray (5Y 8/1). *Zoophycos* burrows common. Pale green (5G 7/2) layers common. Medium dark gray (N4) streaks throughtout — pyrite?.

SMEAR SLIDE SUMMARY:

	1, 66	6, 80	6, 137
	D	M	M
Texture:			
Sand	C	C	C
Silt	C	C	C
Clay	D	A	A
Composition:			
Feldspar	–	–	T
Clay minerals (incl. mica)	–	T	T
Volcanic glass	T	T	T
Pyrite	–	T	T
Foraminifers	C	A	A
Calc. nannofossils	D	A	A

SITE 590 HOLE B CORE 40 CORED INTERVAL 364.7–374.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri
NN9
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Gap
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
N8

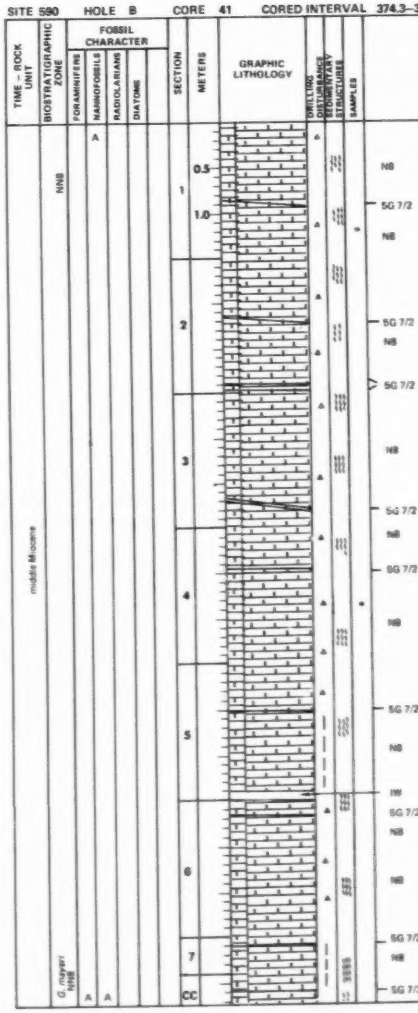
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated. Burrows light gray (N7) to yellowish gray (5Y 8/1). *Zoophycos* apparent, pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	1, 82	6, 78
	D	M
Texture:		
Sand	C	C
Silt	C	C
Clay	D	D
Composition:		
Feldspar	T	T
Mica	T	–
Volcanic glass	T	T
Pyrite	–	T
Zeolite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 41 CORED INTERVAL 374.3–383.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN8
G. mayeri
NN8
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
IW
5G 7/2
N8
N8
5G 7/2
N8
5G 7/2

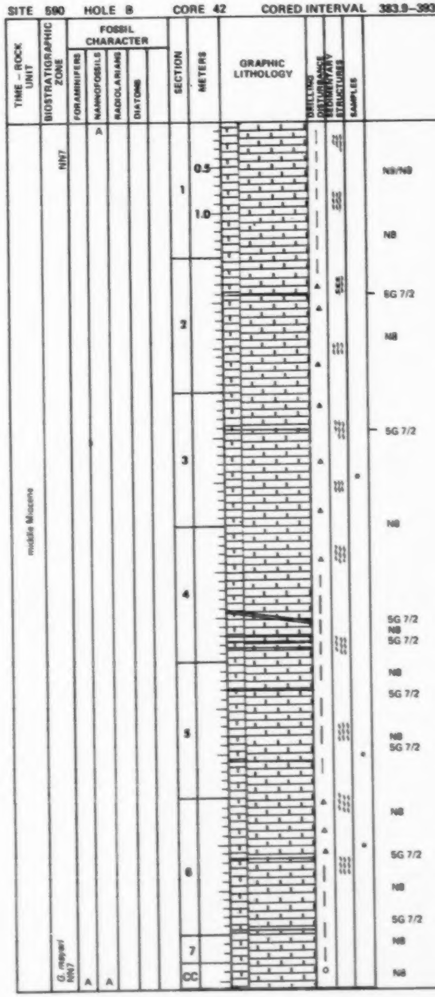
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated, burrows light gray (N7) to yellowish gray (5Y 8/1). Pale green (5G 7/2) layers common. Medium dark gray (N4) streaks throughout.

SMEAR SLIDE SUMMARY:

	1, 119	4, 78
	D	D
Texture:		
Sand	C	C
Silt	C	C
Clay	D	D
Composition:		
Quartz	T	–
Mica	–	T
Volcanic glass	T	T
Pyrite	T	–
Zeolite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 42 CORED INTERVAL 383.9–393.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN7
G. mayeri
NN7
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N9/N8
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
N8

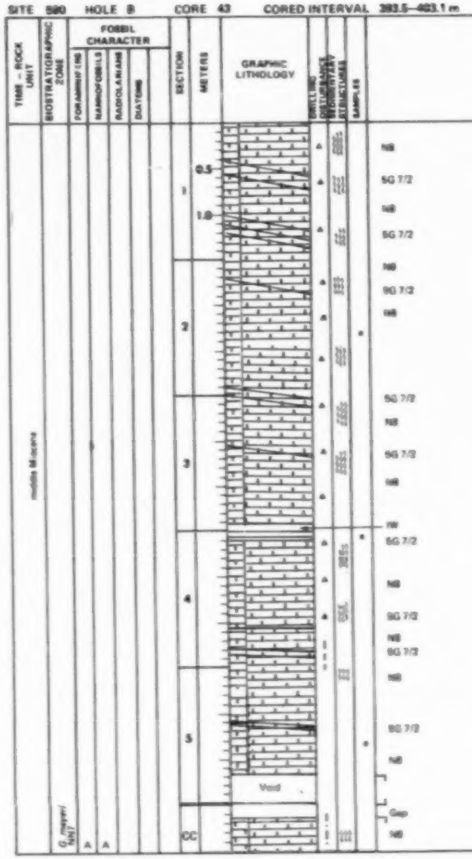
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to white (N9). Moderate to intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers occur. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	3, 93	5,110	6, 48
	D	M	M
Texture:			
Sand	C	C	C
Silt	C	C	C
Clay	D	A	D
Composition:			
Clay minerals (incl. mica)	T	T	–
Volcanic glass	T	T	T
Pyrite	T	T	R
Foraminifers	C	A	C
Calc. nannofossils	D	A	D
Radiolarians	T	–	–

SITE 590 HOLE B CORE 43 CORED INTERVAL 393.5–403.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN7
A
A
1
2
3
4
5
CC
0.5
1.0
Void
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
IW
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
Gap
N8

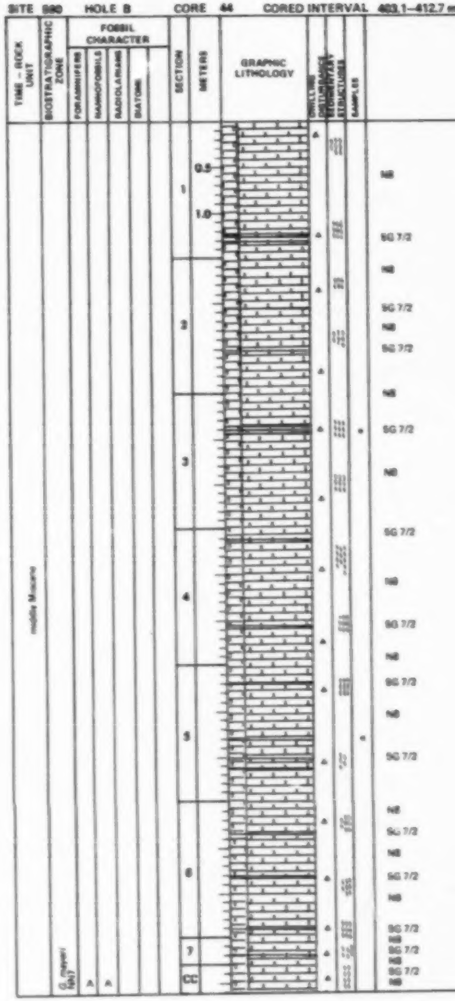
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY

	2, 79 M	4, 6 M	5, 83 D
Texture:			
Sand	C	C	R
Silt	C	C	C
Clay	A	D	D
Composition:			
Clay minerals (incl. mica)	T	T	T
Volcanic glass	T	T	T
Pyrite	T	T	T
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE B CORE 44 CORED INTERVAL 403.1–412.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN7
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8
5G 7/2
N8

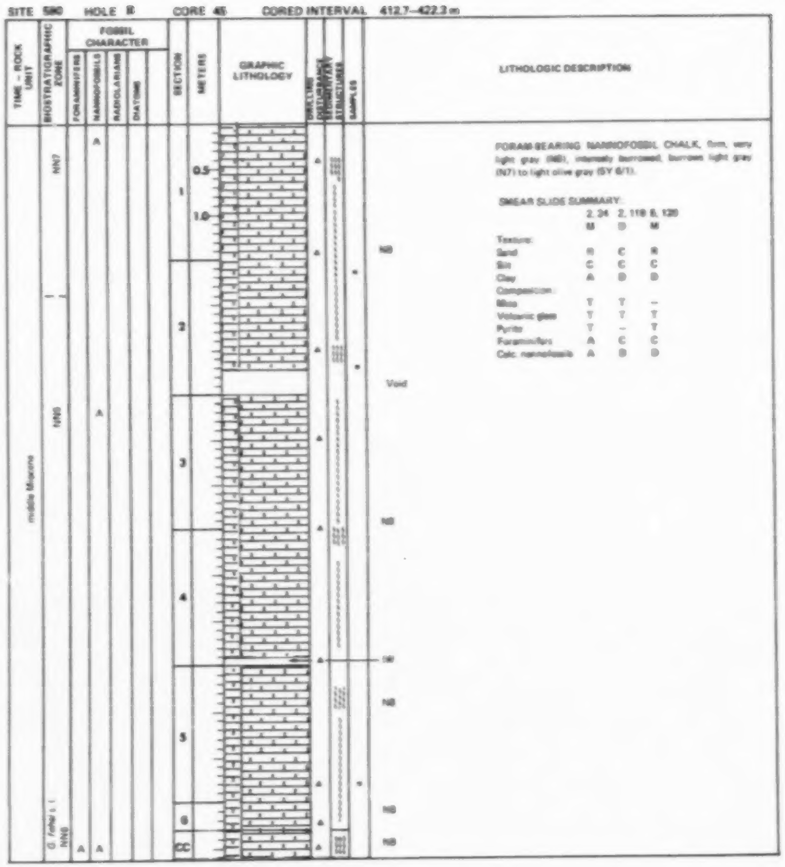
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	5, 79 D	3, 37 M
Texture:		
Sand	R	R
Silt	C	A
Clay	D	A
Composition:		
Feldspar	–	T
Mica	T	T
Volcanic glass	T	–
Pyrite	T	C
Foraminifers	C	C
Calc. nannofossils	D	A

SITE 590 HOLE B CORE 45 CORED INTERVAL 412.7–422.3 m

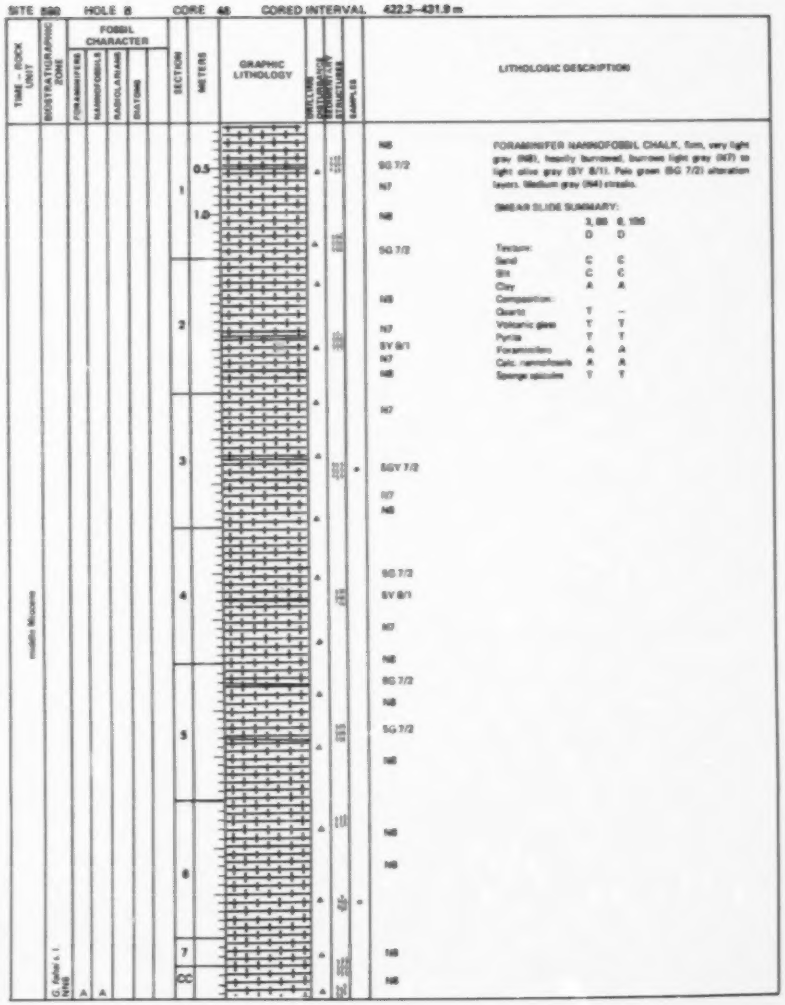

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
NN7
NN6
G. fohsi s. l.
NN6
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
Void
N8
N8
N8
N8
N8

FORAM-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1).

SMEAR SLIDE SUMMARY:

	2, 24 M	2, 119 D	6, 120 M
Texture:			
Sand	R	C	R
Silt	C	C	C
Clay	A	D	D
Composition:			
Mica	T	T	–
Volcanic glass	T	T	T
Pyrite	T	–	T
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE B CORE 46 CORED INTERVAL 422.3–431.9 m

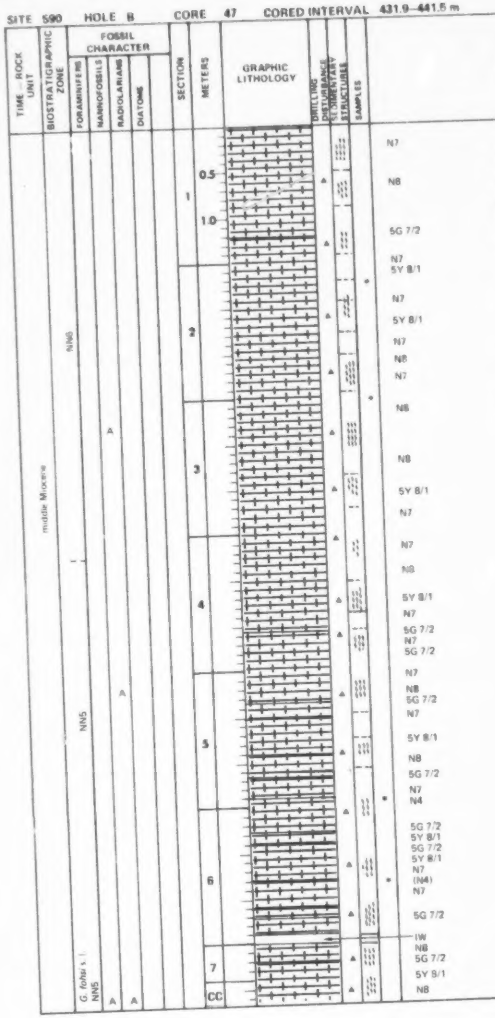

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. fohsi s. l.
NN6
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5G 7/2
N7
N8
5G 7/2
N8
N7
5Y 8/1
N7
N8
N7
5GY 7/2
N7
N8
5G 7/2
5Y 8/1
N7
N8
5G 7/2
N8
5G 7/2
N8
N8
N8
N8
N8

FORAMINIFER NANNOFOSSIL CHALK, firm, very light gray (N8), heavily burrowed, burrows light gray (N7) to light olive gray (5Y 8/1). Pale green (5G 7/2) alteration layers. Medium gray (N4) streaks.

SMEAR SLIDE SUMMARY:

	3, 80 D	6, 100 D
Texture:		
Sand	C	C
Silt	C	C
Clay	A	A
Composition:		
Quartz	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	A	A
Calc. nannofossils	A	A
Sponge spicules	T	T

SITE 590 HOLE B CORE 47 CORED INTERVAL 431.9–441.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
NN5
G. fohsi s. l.
NN5
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N8
5G 7/2
N7
5Y 8/1
N7
5Y 8/1
N7
N8
N7
N8
N8
5Y 8/1
N7
N7
N8
5Y 8/1
N7
5G 7/2
N7
5G 7/2
N7
N8
5G 7/2
N7
5Y 8/1
N8
5G 7/2
N7
N4
5G 7/2
5Y 8/1
5G 7/2
5Y 8/1
N7
(N4)
N7
5G 7/2
IW
N8
5G 7/2
5Y 8/1
N8

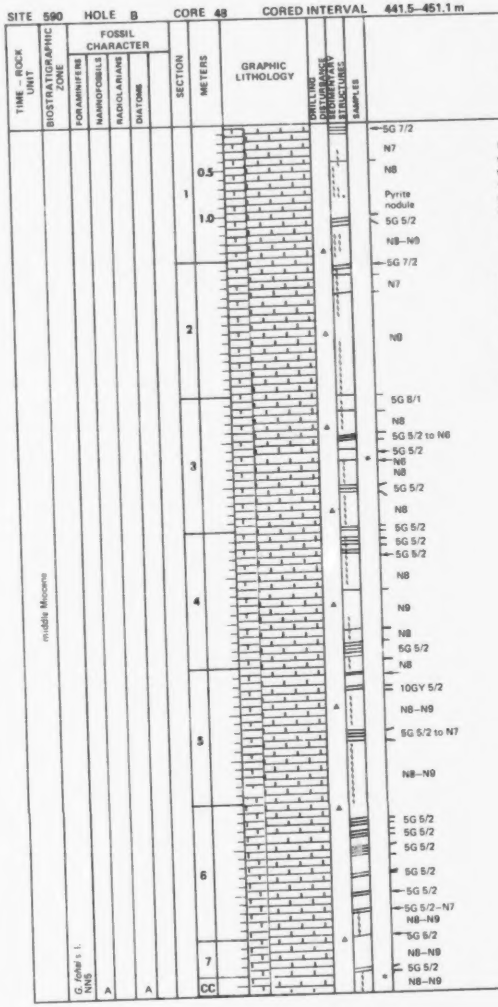
LITHOLOGIC DESCRIPTION

NANNOFOSSIL FORAMINIFER CHALK, firm, very light gray (N8) to light gray (N7) to light olive gray (5Y 8/1) with pale green (5G 7/2) and medium dark gray (N4) streaks. Intensely bioturbated. Burrows concentrated in light (N7–N8) zones. Contacts gradational. Light (N8) zones lower in foraminifers becoming a foraminifer nannofossil chalk.

SMEAR SLIDE SUMMARY

	2, 27 D	3, 4 D	5, 140 D	6, 87 M
Texture:				
Sand	C	C	C	C
Silt	A	A	C	A
Clay	A	A	A	A
Composition:				
Feldspar	T	T	T	–
Mica	T	–	T	T
Volcanic glass	T	T	T	T
Pyrite	–	T	T	R
Carbonate unspec.	T	–	–	–
Foraminifers	A	A	A	A
Calc. nannofossils	A	A	A	A

SITE 590 HOLE B CORE 48 CORED INTERVAL 441.5–451.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s. l.
NN5
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5G 7/2
N7
N8
Pyrite nodule
5G 5/2
N8–N9
5G 7/2
N7
N8
5G 8/1
N8
5G 5/2 to N8
5G 5/2
N8
N8
5G 5/2
N8
5G 5/2
5G 5/2
5G 5/2
N8
N9
N8
5G 5/2
N8
10GY 5/2
N8–N9
5G 5/2 to N7
N8–N9
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2–N7
N8–N9
5G 5/2
N8–N9
5G 5/2
N8–N9

LITHOLOGIC DESCRIPTION

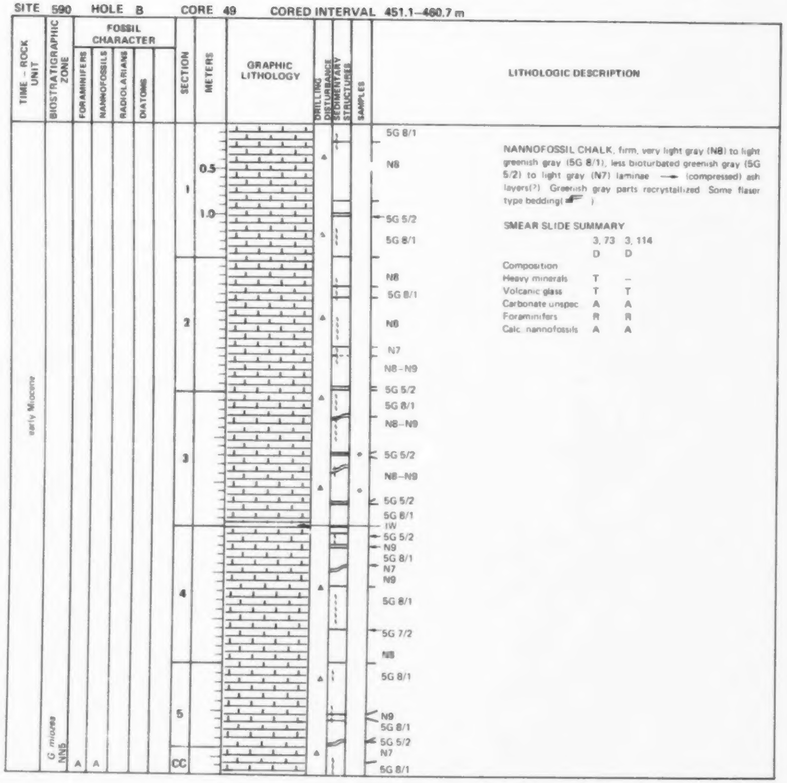
FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light gray (N7). Moderately bioturbated (*Planolites*, beautiful *Zoophycos*) burrows grayish yellow green (5GY 7/2). Thin pale green (5G 7/2) to grayish green (5G 5/2) laminae ↳ (compressed) ash layers(?).

SMEAR SLIDE SUMMARY:

	3, 85 D	CC[1] M
Composition:		
Volcanic glass	T	R
Pyrite	–	T
Zeolite	–	A
Carbonate unspec.	A	–
Foraminifers	C	–
Calc. nannofossils	A	–

[1] Insoluble residue

SITE 590 HOLE B CORE 49 CORED INTERVAL 451.1–460.7 m

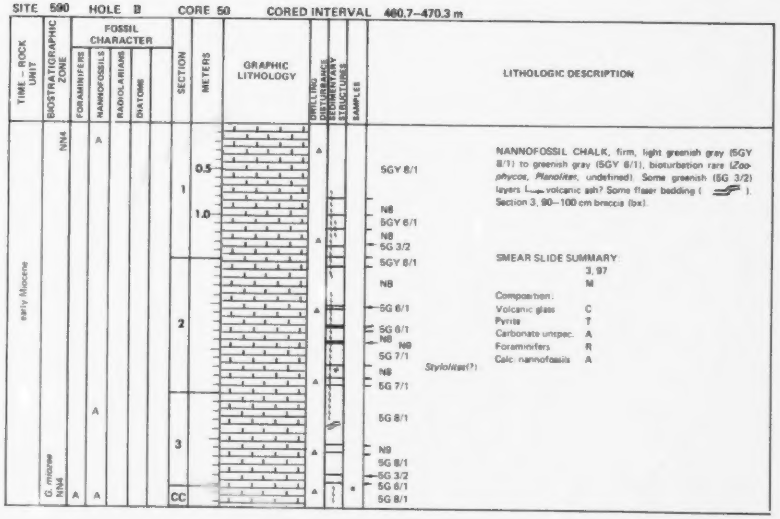

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
G. miozea
NN5
A
A
1
2
3
4
5
CC
0.5
1.0
5G 8/1
N8
5G 5/2
5G 8/1
N8
5G 8/1
N8
N7
N8–N9
5G 5/2
5G 8/1
N8–N9
5G 5/2
N8–N9
5G 5/2
5G 8/1
IW
5G 5/2
N9
5G 8/1
N7
N9
5G 8/1
5G 7/2
N8
5G 8/1
N9
5G 8/1
5G 5/2
N7
5G 8/1

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1), less bioturbated greenish gray (5G 5/2) to light gray (N7) laminae ⟶ (compressed) ash layers(?) Greenish gray parts recrystallized. Some flaser type bedding( )

SMEAR SLIDE SUMMARY

	3, 73	3, 114
	D	D
Composition		
Heavy minerals	T	–
Volcanic glass	T	T
Carbonate unspec	A	A
Foraminifers	R	R
Calc. nannofossils	A	A

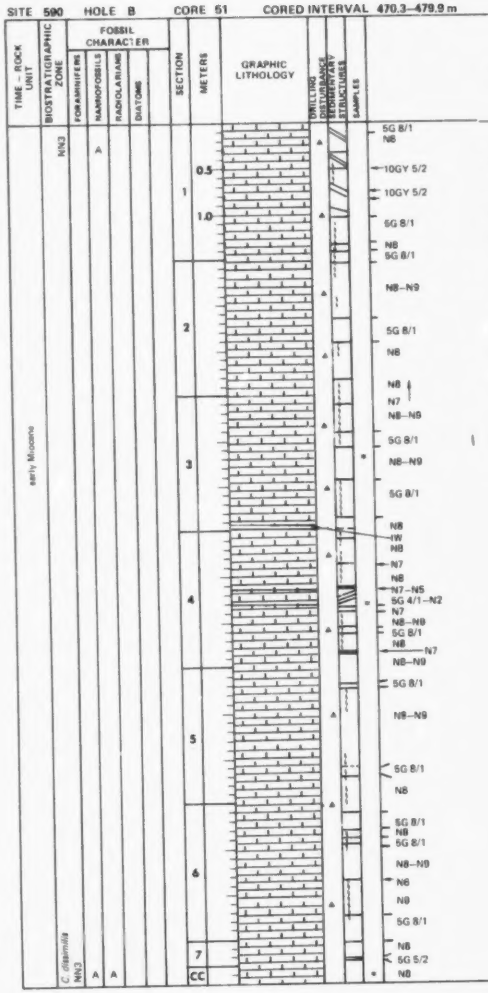
SITE 590 HOLE B CORE 50 CORED INTERVAL 460.7–470.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
NN4
G. miozea
NN4
A
A
A
A
1
2
3
CC
0.5
1.0
5GY 8/1
N8
5GY 6/1
N8
5G 3/2
5GY 6/1
N8
5G 6/1
5G 6/1
N8
N9
5G 7/1
N8
5G 7/1
5G 8/1
N9
5G 8/1
5G 3/2
5G 6/1
5G 8/1
Stylolites(?)

NANNOFOSSIL CHALK, firm, light greenish gray (5GY 8/1) to greenish gray (5GY 6/1), bioturbation rare (*Zoophycos*, *Planolites*, undefined). Some greenish (5G 3/2) layers ⟶ volcanic ash? Some flaser bedding ( ). Section 3, 90–100 cm breccia (bx).

SMEAR SLIDE SUMMARY:

	3, 97
	M
Composition:	
Volcanic glass	C
Pyrite	T
Carbonate unspec.	A
Foraminifers	R
Calc. nannofossils	A


SITE 590 HOLE B CORE 51 CORED INTERVAL 470.3–479.9 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN3
C. dissimilis
NN3
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 8/1
N8
10GY 5/2
10GY 5/2
5G 8/1
N8
5G 8/1
N8–N9
5G 8/1
N8
N8
N7
N8–N9
5G 8/1
N8–N9
5G 8/1
N8
IW
N8
N7
N8
N7–N5
5G 4/1–N2
N7
N8–N9
5G 8/1
N8
N7
N8–N9
5G 8/1
N8–N9
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8–N9
N6
N8
5G 8/1
N8
5G 5/2
N8

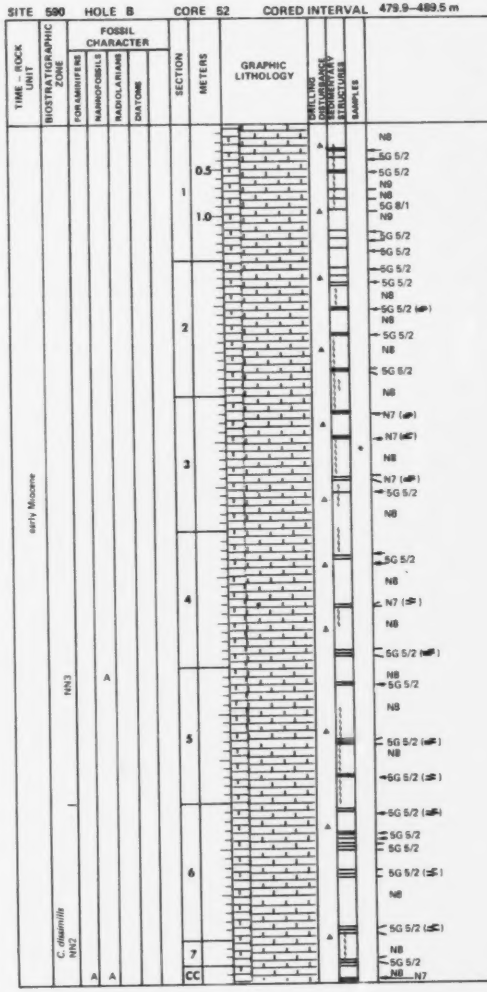
LITHOLOGIC DESCRIPTION

RECRYSTALLIZED NANNOFOSSIL CHALK, firm, very light gray (N8) and white (N9) to greenish gray (5GY 6/1), bioturbation moderate (*Planolites, Zoophycos, Chondrites*) Section 1: thin, angular (~ 30°) laminae (greenish gray [10GY 5/2]) in the upper part of the section, near 50 cm flaser bedding. Section 4: 66–82 cm interval dark greenish gray (5G 4/1) to grayish black (N2) part, fine laminae, *Chondrites*. Smear slide →ALTERED VOLCANIC GLASS (palagonite)

SMEAR SLIDE SUMMARY

	3, 70 D	4, 82 M	CC[1] M
Composition:			
Quartz	–	T	–
Feldspar	–	T	–
Clay (smectite?)	–	R	C
Volcanic glass	T	–	C
Palagonite	–	A	–
Pyrite	–	–	C
Carbonate unspec.	A	–	–
Foraminifers	R	–	–
Calc. nannofossils	A	R	–

[1] Insol. residue


SITE 590 HOLE B CORE 52 CORED INTERVAL 479.9–489.5 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN3
C. dissimilis
NN2
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5G 5/2
5G 5/2
N9
N8
5G 8/1
N9
5G 5/2
5G 5/2
5G 5/2
5G 5/2
N8
5G 5/2
N8
5G 5/2
N8
5G 5/2
N8
N7
N7
N8
N7
5G 5/2
N8
5G 5/2
N8
N7
N8
5G 5/2
N8
5G 5/2
N8
5G 5/2
N8
5G 5/2
5G 5/2
5G 5/2
5G 5/2
5G 5/2
N8
5G 5/2
N8
5G 5/2
N8
N7

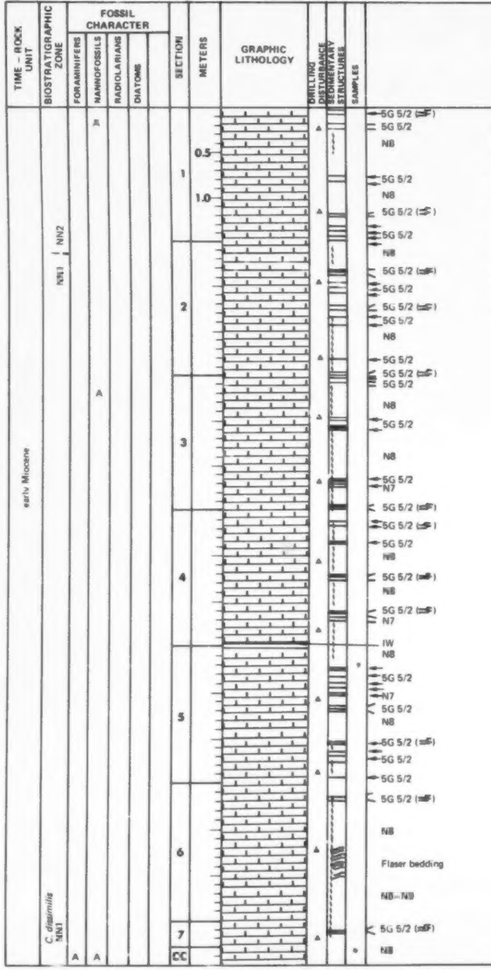
LITHOLOGIC DESCRIPTION

RECRYSTALLIZED FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1), moderately bioturbated (*Planolites, Zoophycos*). Thin, grayish green (5G 5/2) laminae ↳ volcanic ash layers(?), flaser bedding (⥱).

SMEAR SLIDE SUMMARY:

	3, 65 D
Composition:	
Volcanic glass	R
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A

SITE 590 HOLE B CORE 53 CORED INTERVAL 489.5–499.1 m

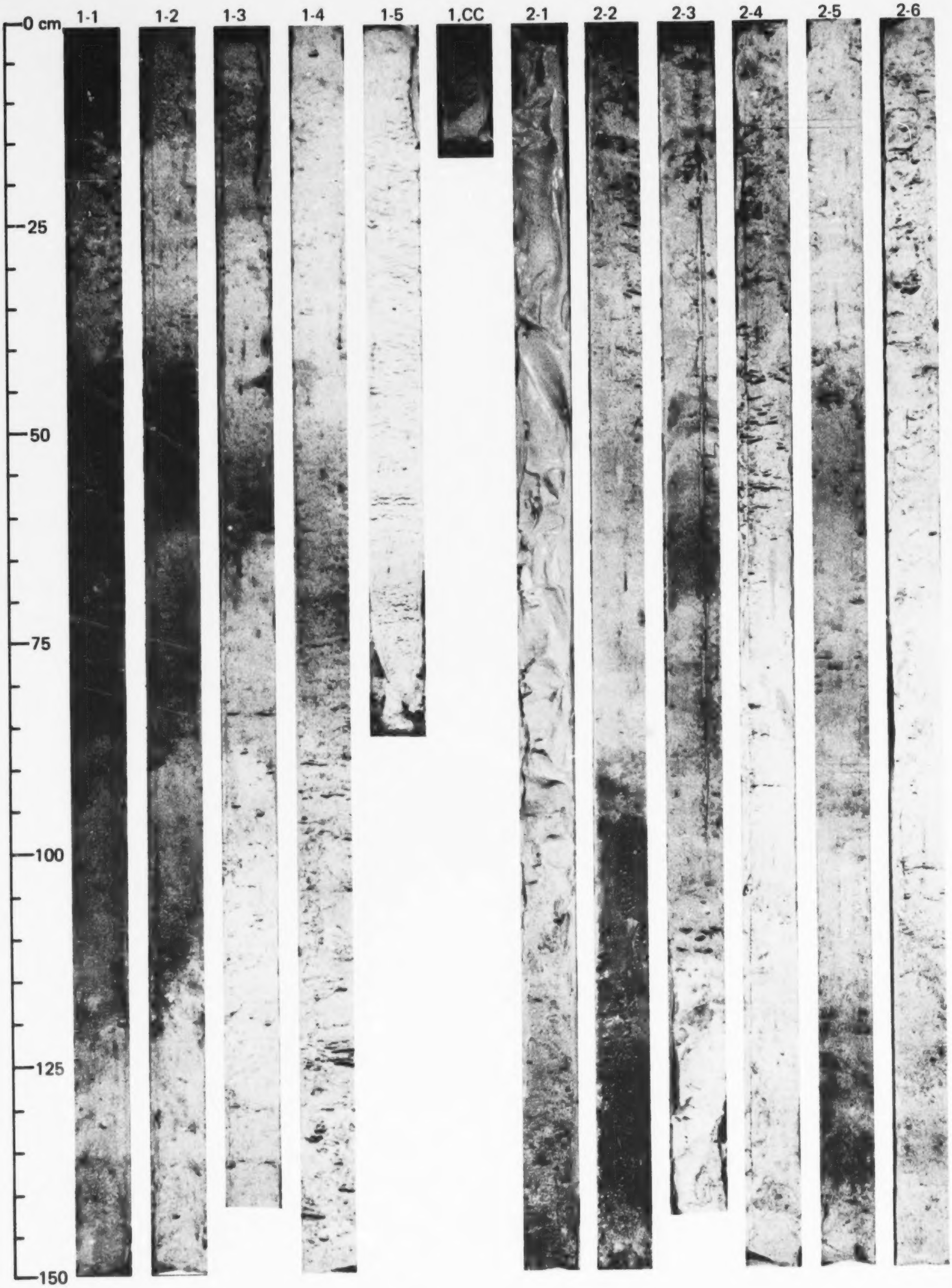

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN1 | NN2
C. dissimilis NN1
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 5/2
5G 5/2
N8
5G 5/2
N8
5G 5/2
5G 5/2
N8
5G 5/2
5G 5/2
5G 5/2
5G 5/2
N8
5G 5/2
5G 5/2
5G 5/2
N8
5G 5/2
N8
5G 5/2
N7
5G 5/2
5G 5/2
5G 5/2
N8
5G 5/2
N8
5G 5/2
N7
IW
N8
5G 5/2
N7
5G 5/2
N8
5G 5/2
5G 5/2
5G 5/2
5G 5/2
N8
Flaser bedding
N8–N9
5G 5/2
N8

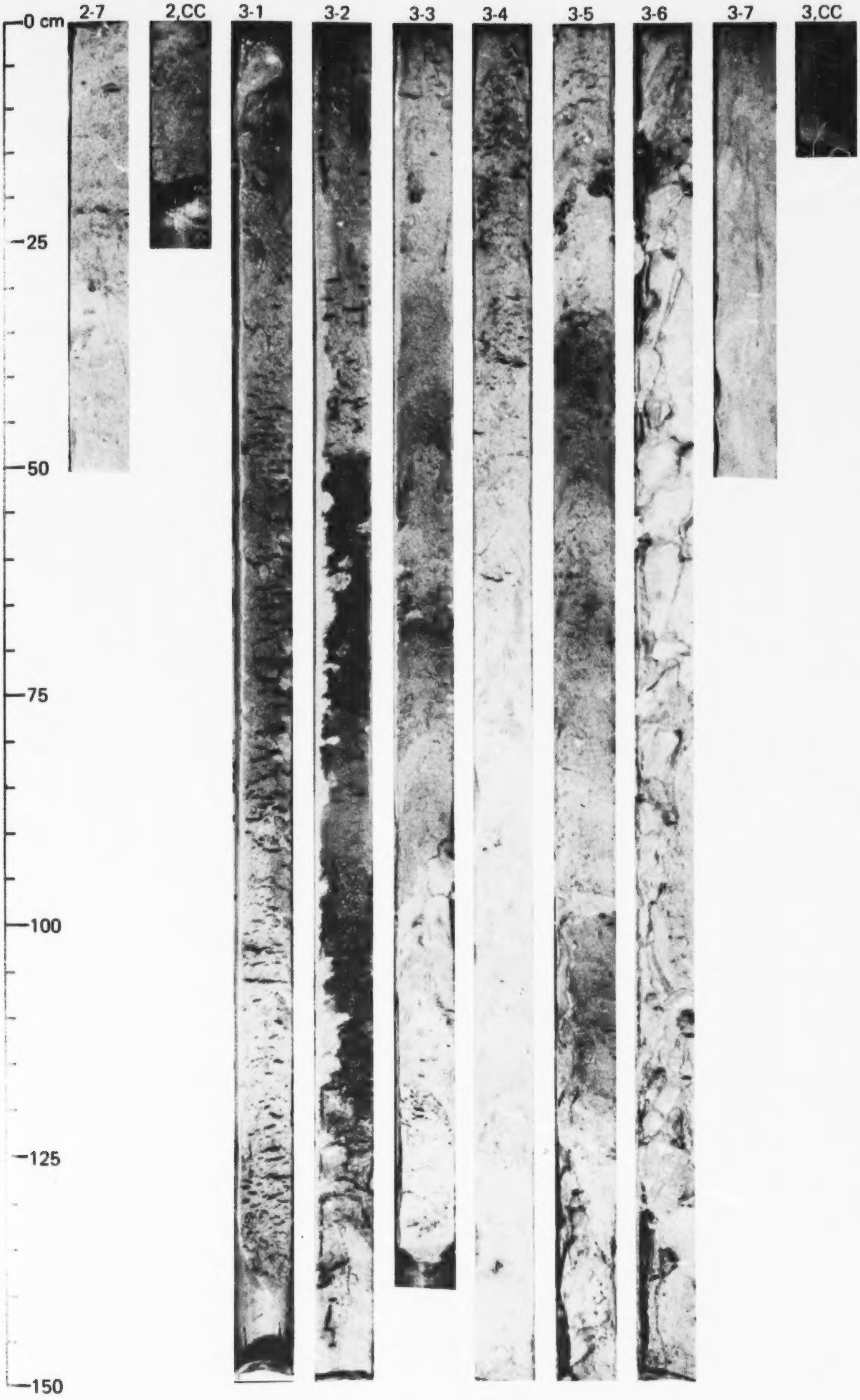
LITHOLOGIC DESCRIPTION

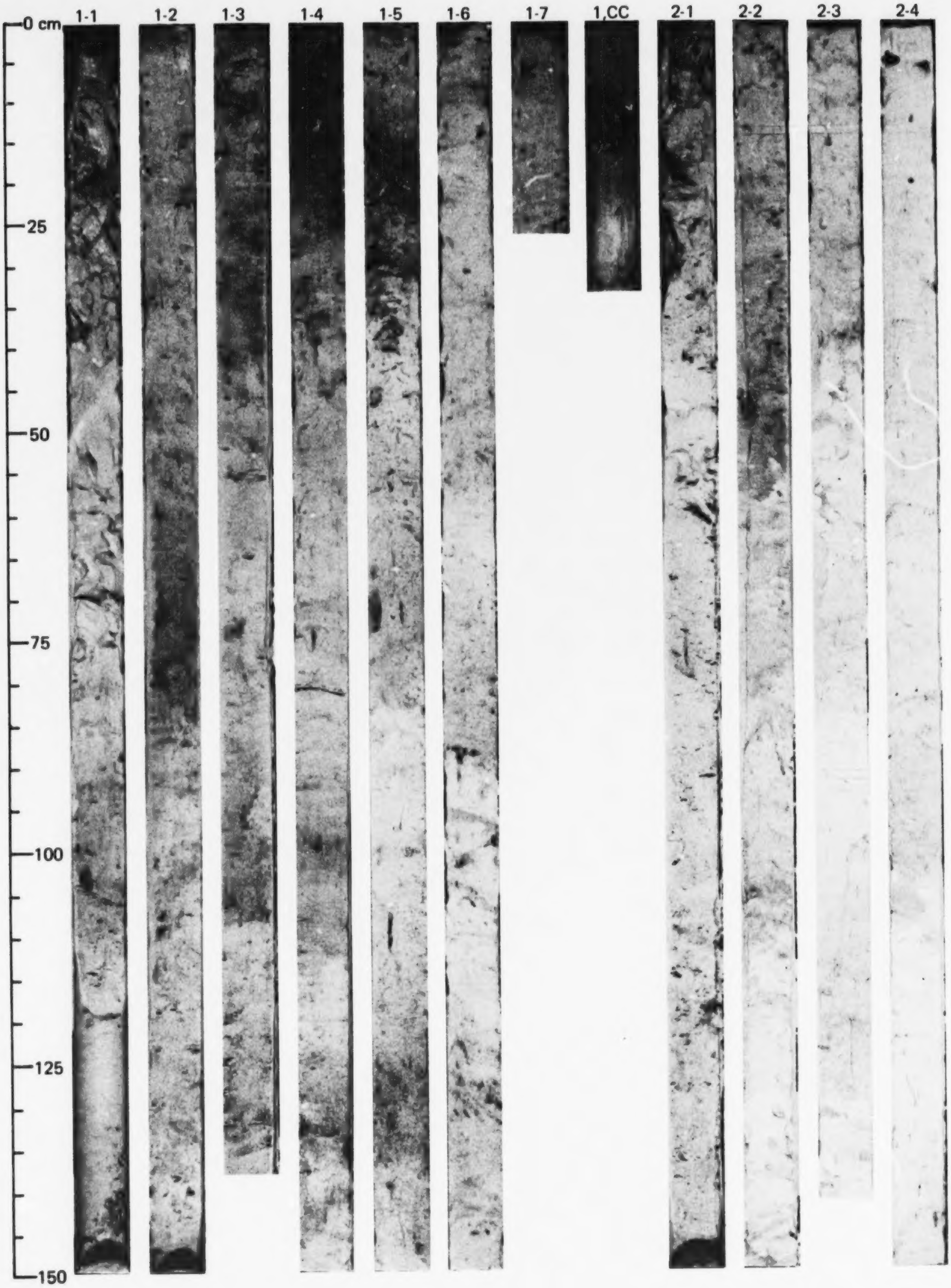
RECRYSTALLIZED NANNOFOSSIL CHALK, firm, very light gray (N8). Some bioturbation. Thin, greenish gray (5G 5/2) laminae ⟶ (compressed) ash layers?. Some dark (N6) spots ⟶ iron sulfide, flaser bedding ( ).

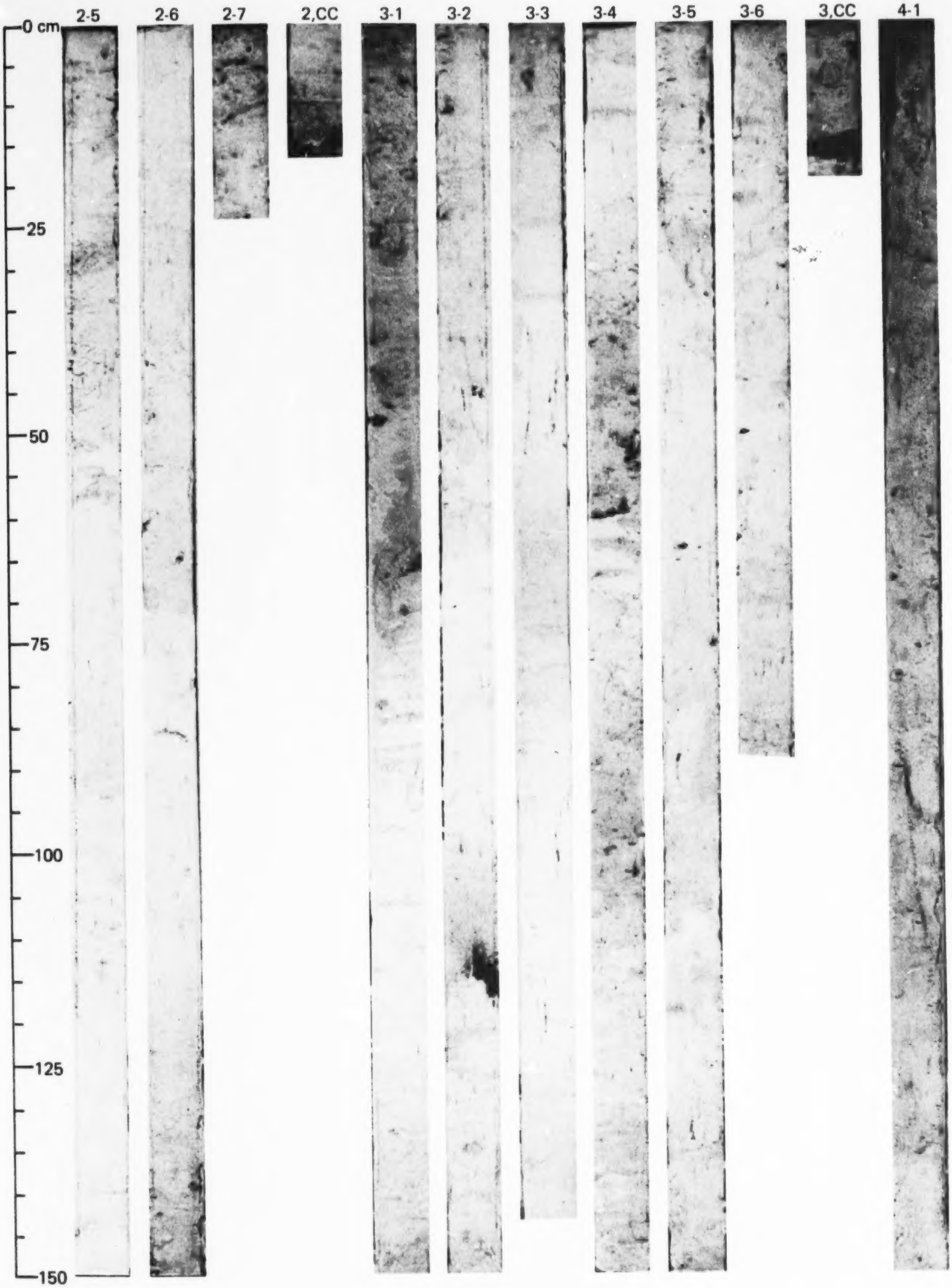
SMEAR SLIDE SUMMARY:

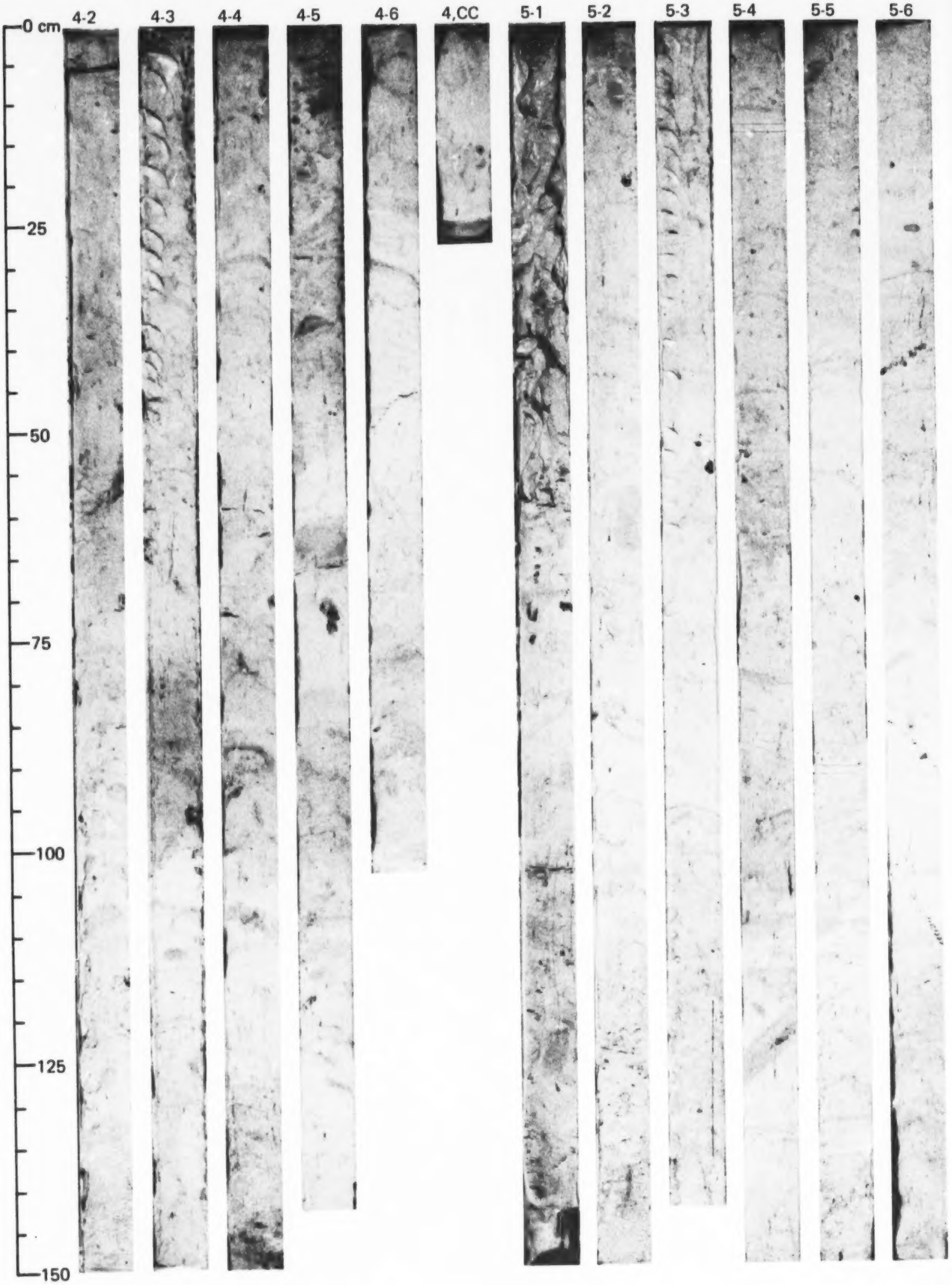
	5, 20	CC¹
	D	M
Composition:		
Volcanic glass	T	C
Zeolites	–	A
Pyrite	–	T
Foraminifers	R	–
Calc. nannofossils	A	–
Carbonate unspec.	A	–

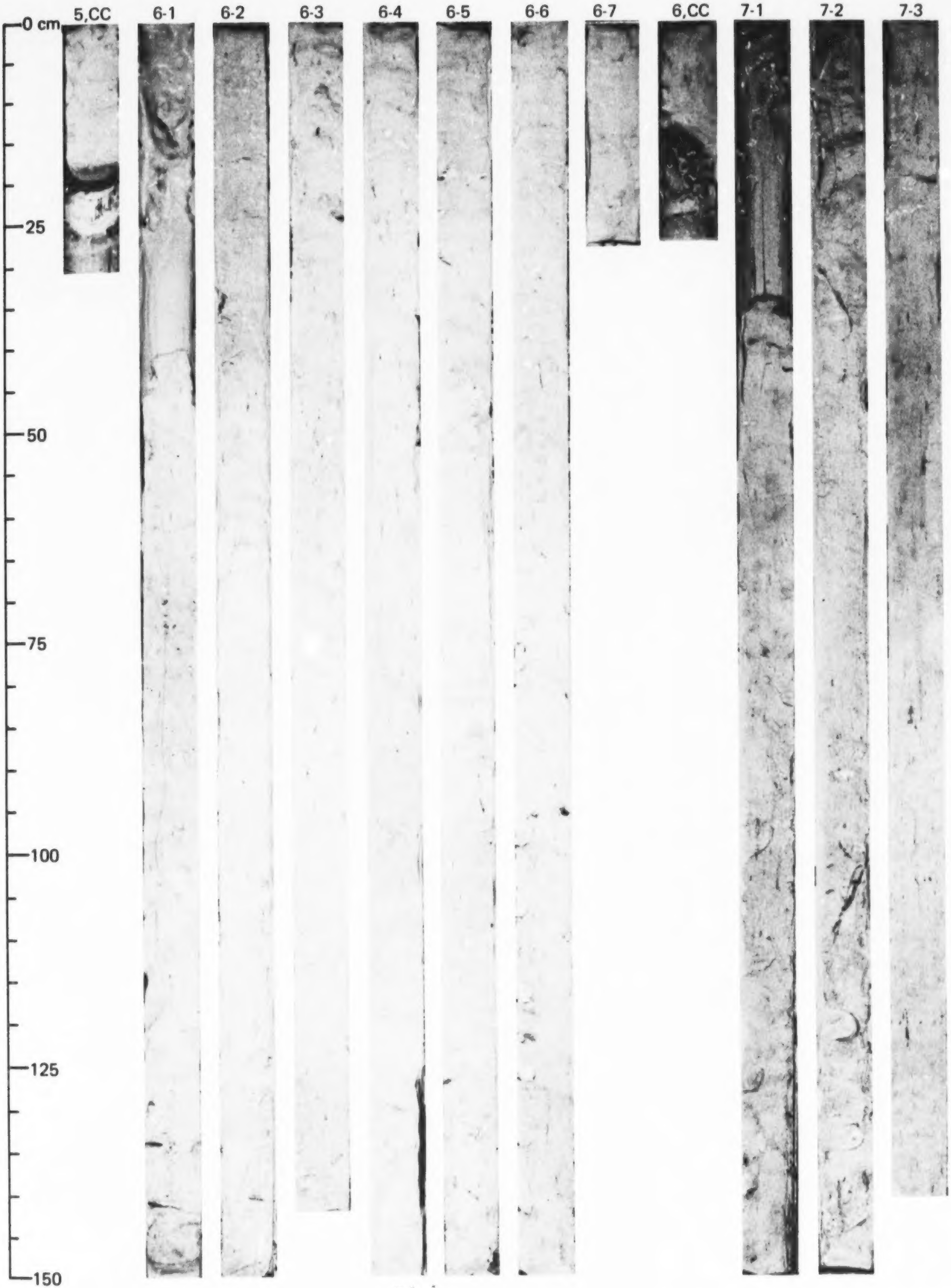

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1,CC
2-1
2-2
2-3
2-4
2-5
2-6

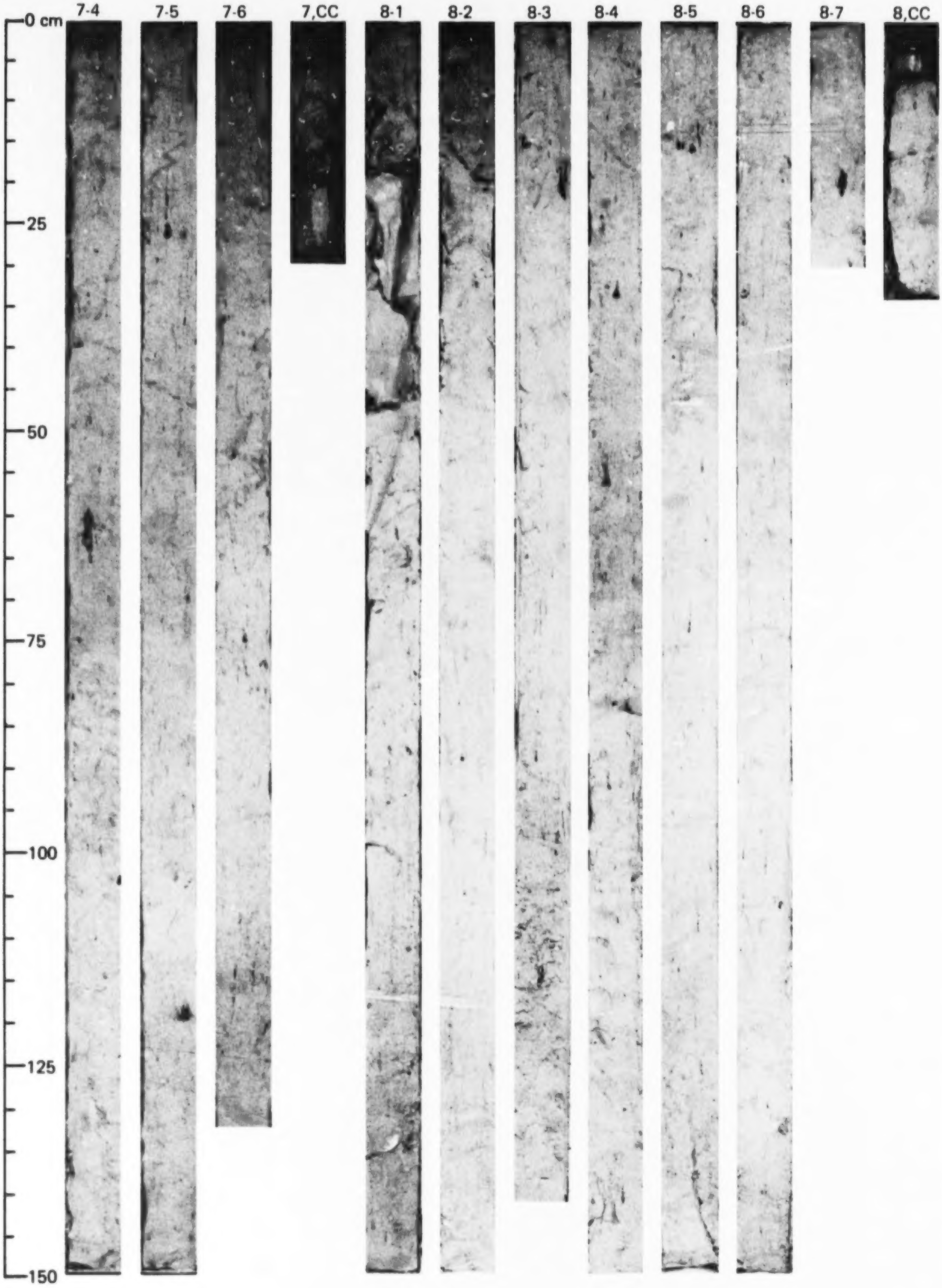

0 cm
25
50
75
100
125
150
2-7
2,CC
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3,CC

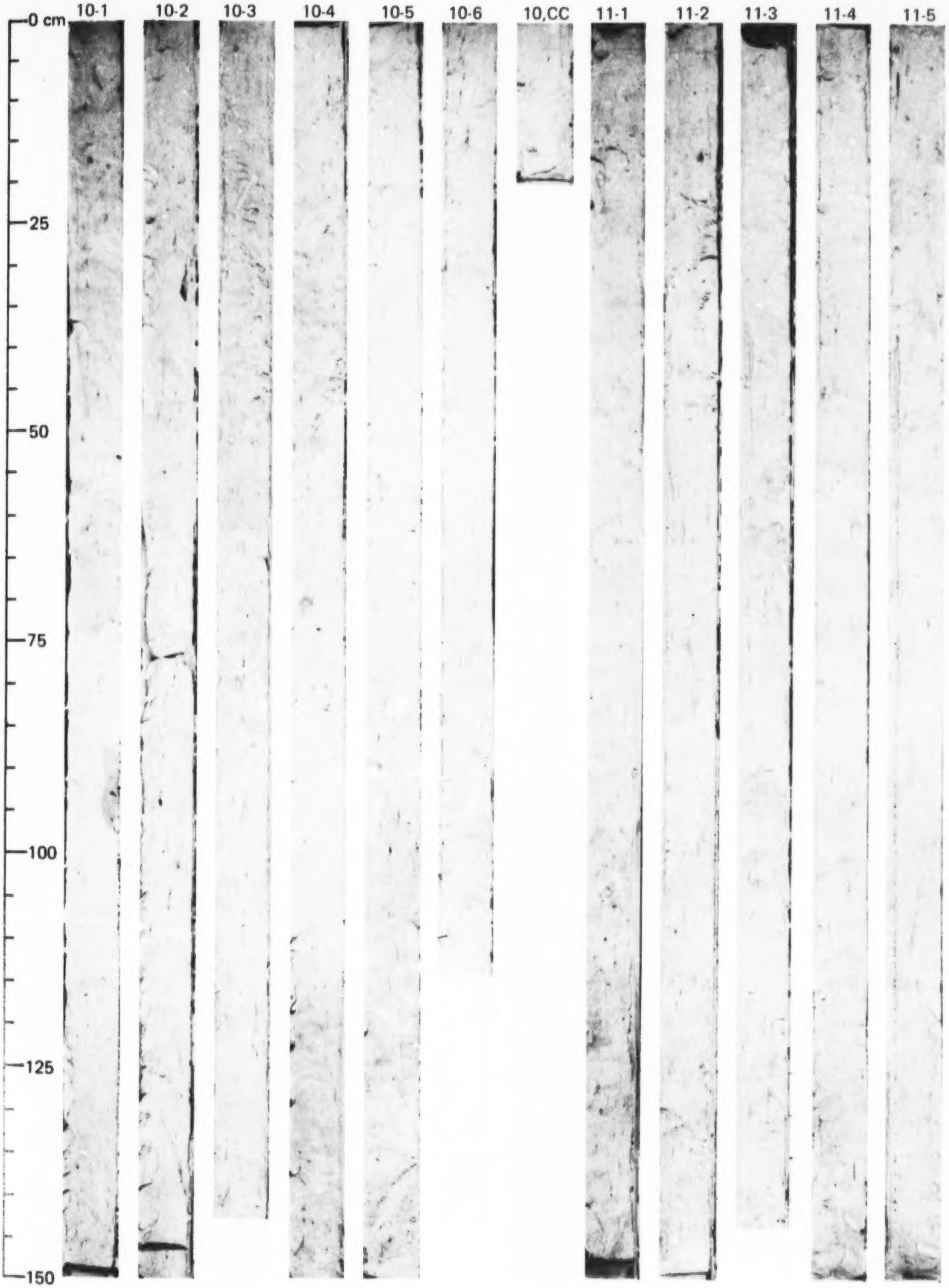

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1,CC
2-1
2-2
2-3
2-4

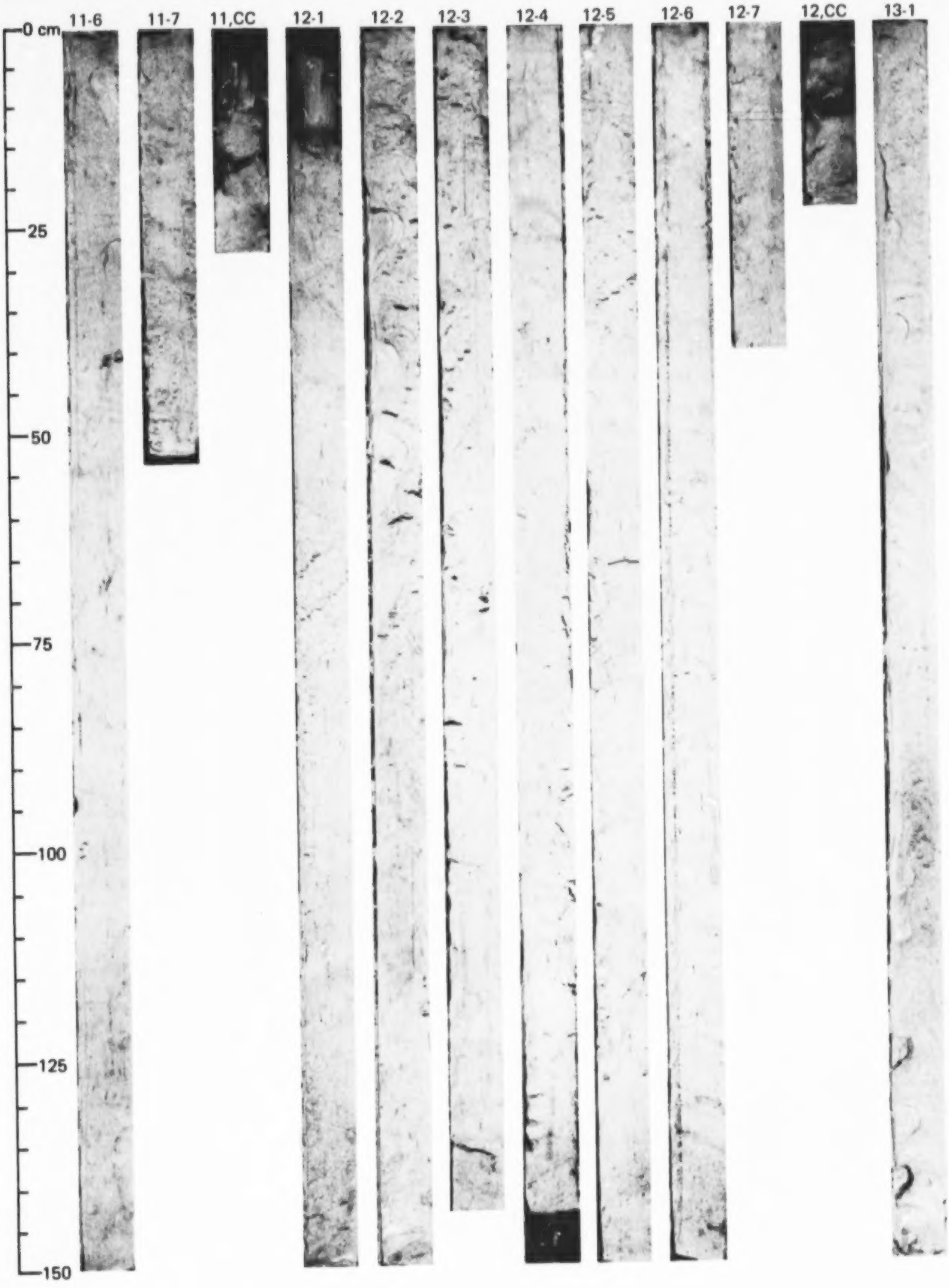

2-5
2-6
2-7
2,CC
3-1
3-2
3-3
3-4
3-5
3-6
3,CC
4-1
0 cm
25
50
75
100
125
150

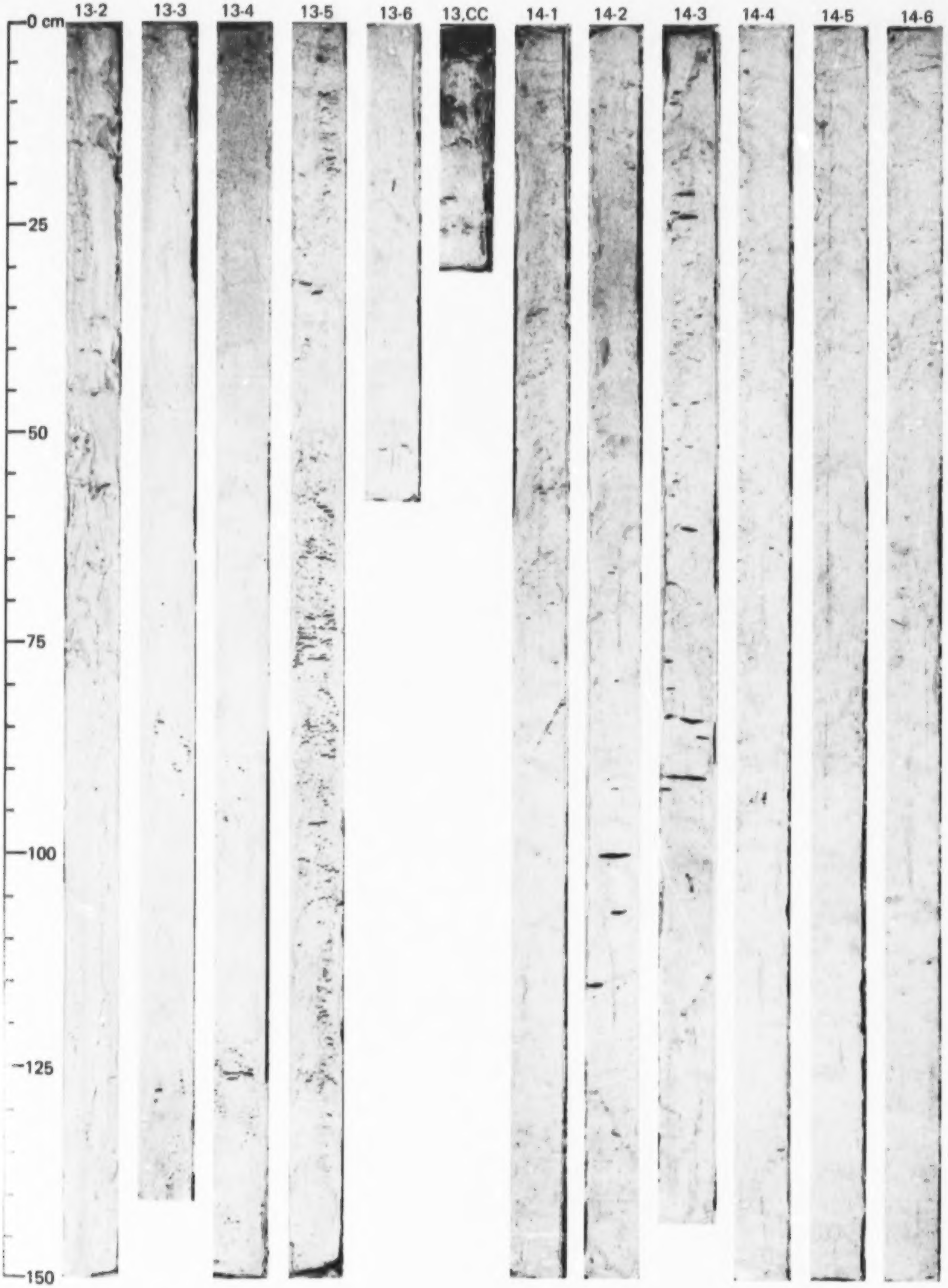

0 cm
25
50
75
100
125
150
4-2
4-3
4-4
4-5
4-6
4,CC
5-1
5-2
5-3
5-4
5-5
5-6

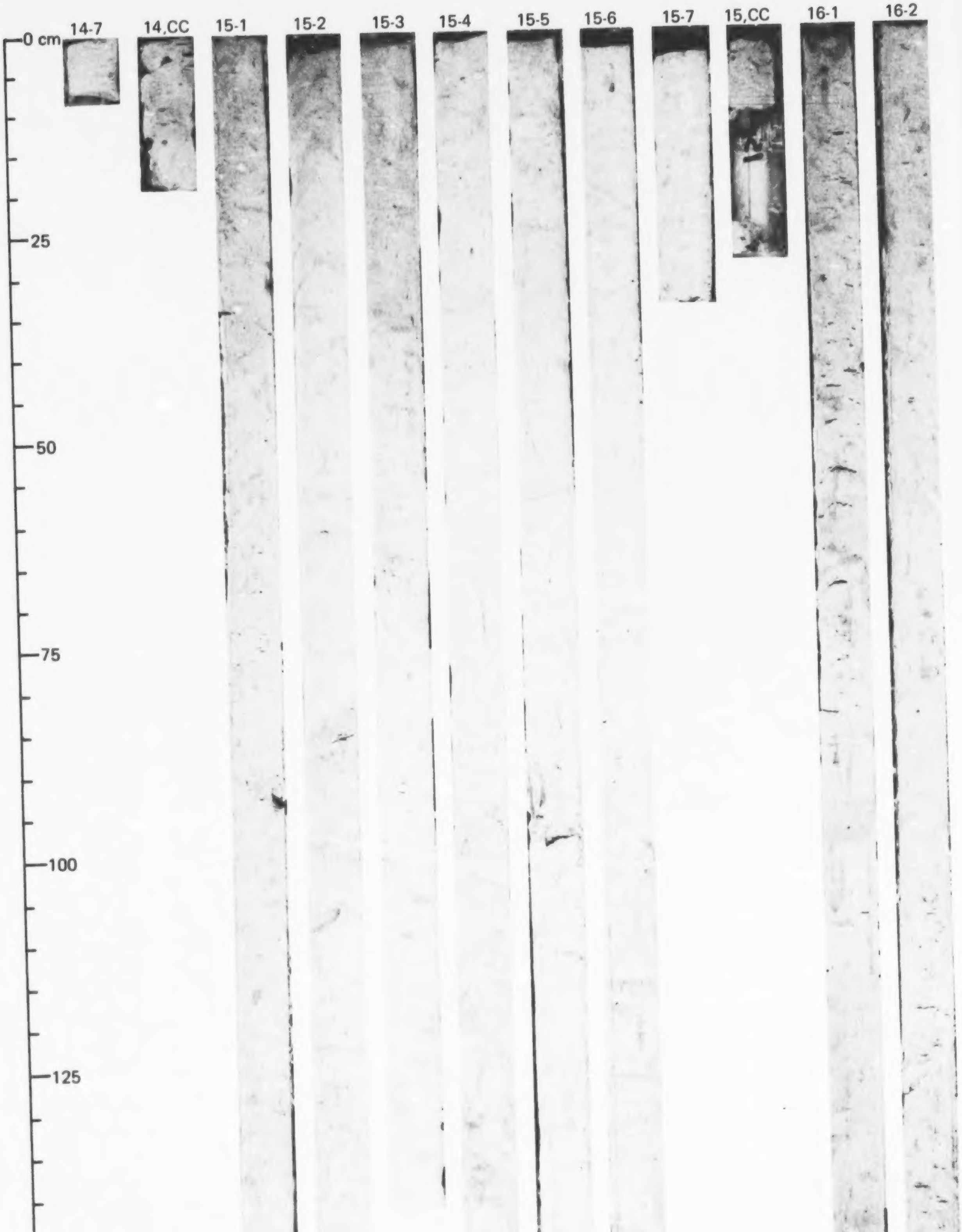

5,CC
6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
0 cm
25
50
75
100
125
150

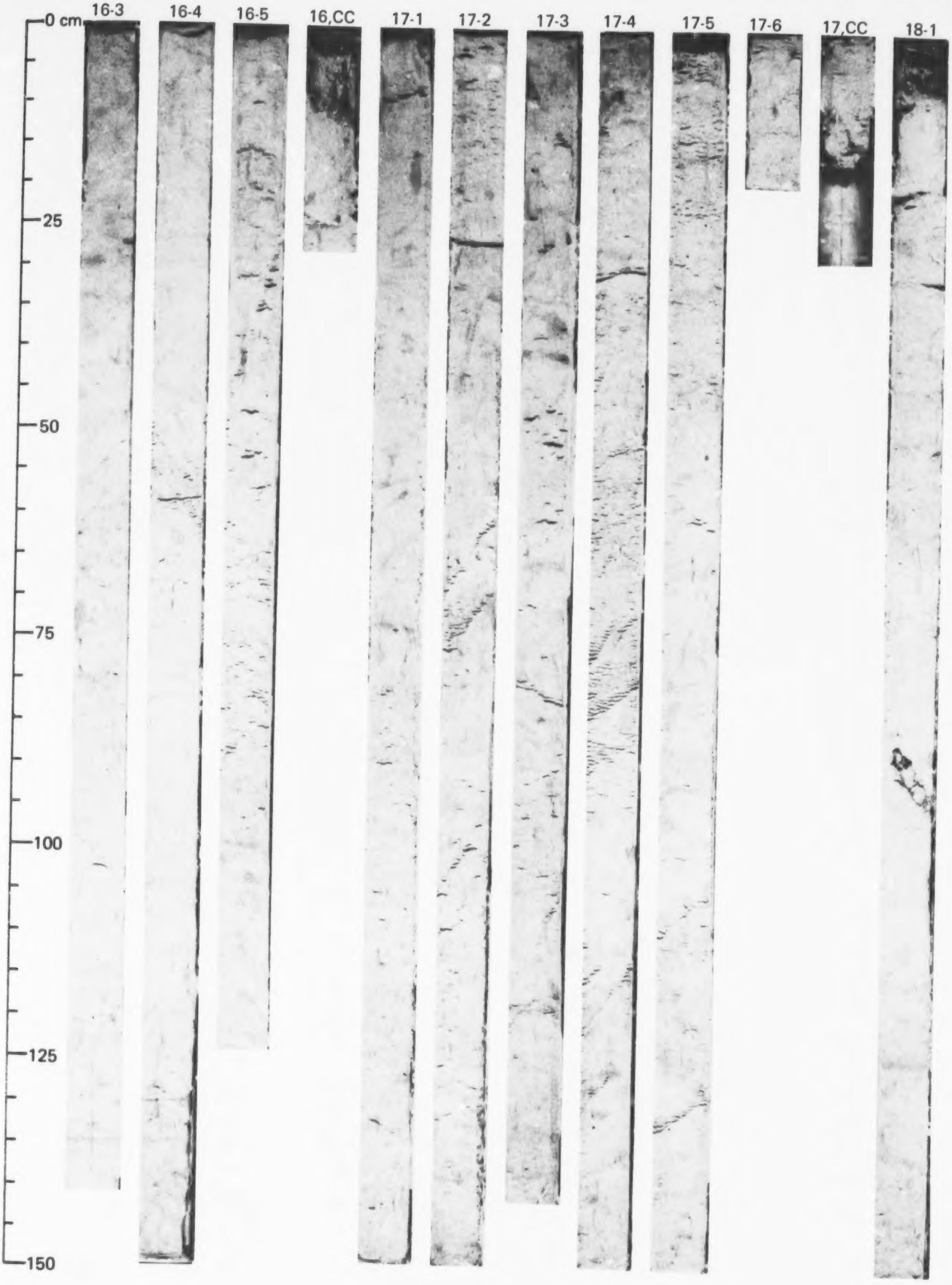

0 cm
25
50
75
100
125
150
7-4
7-5
7-6
7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8-7
8,CC

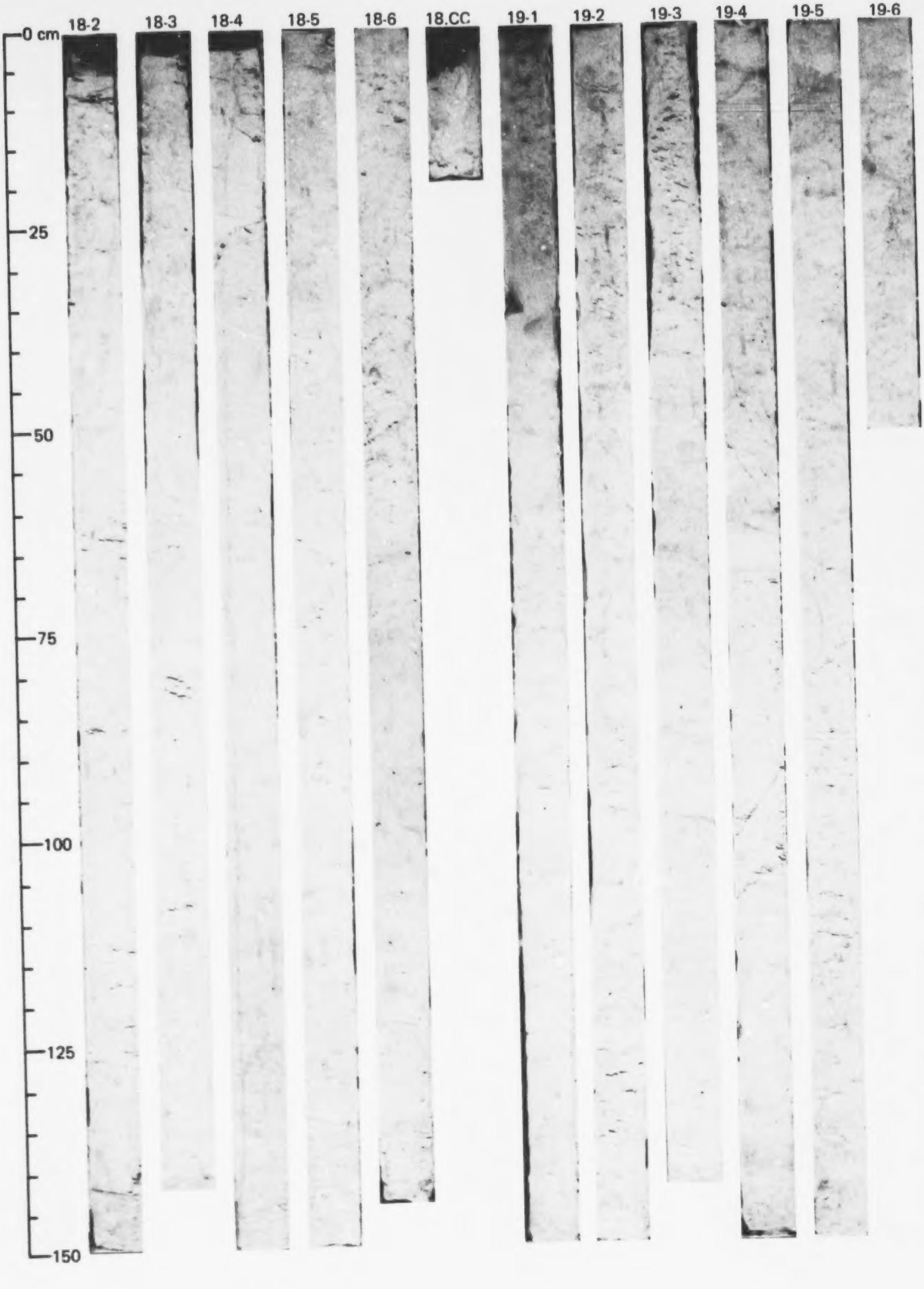

0 cm
25
50
75
100
125
150
10-1
10-2
10-3
10-4
10-5
10-6
10,CC
11-1
11-2
11-3
11-4
11-5

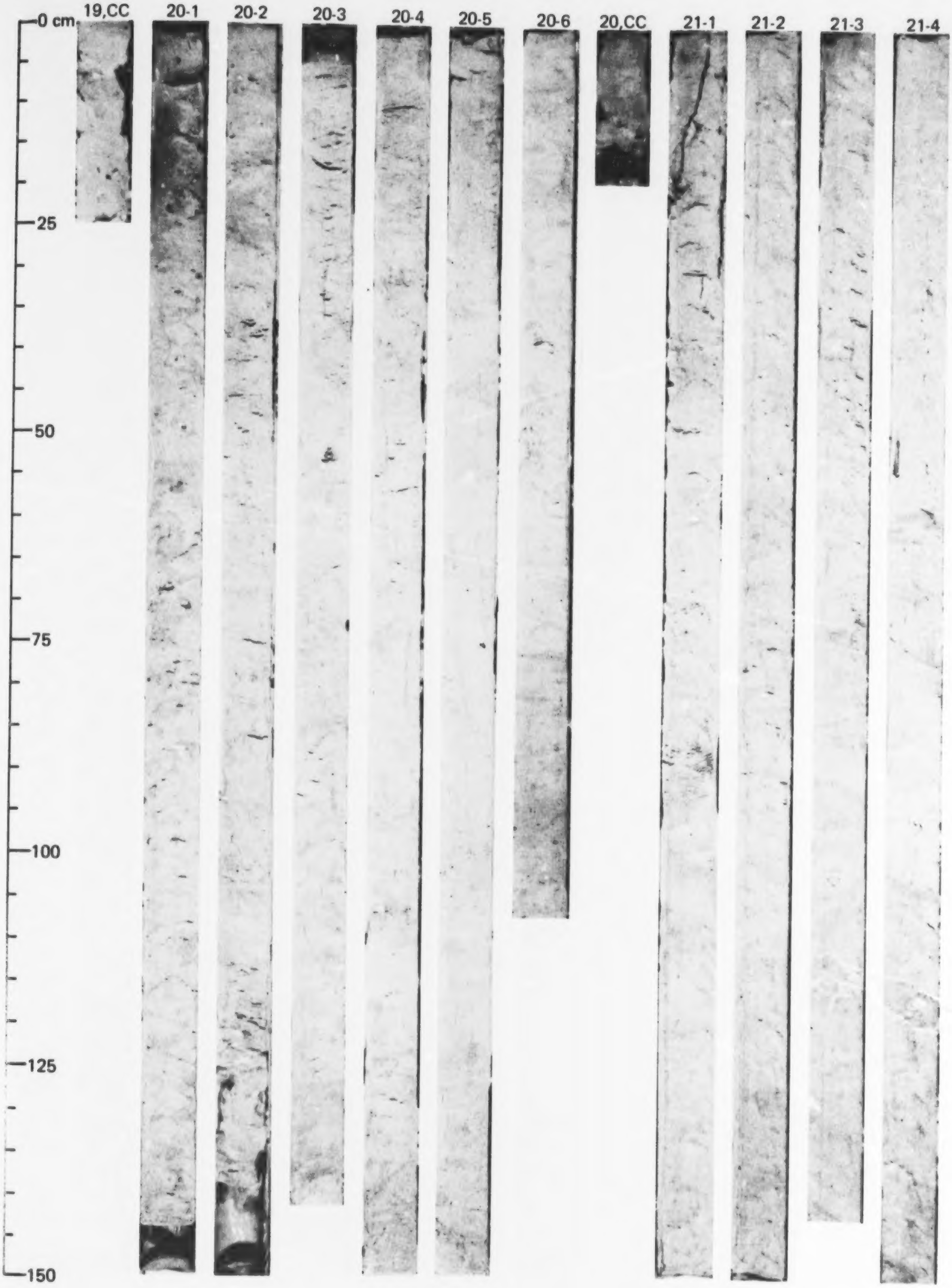

11-6
11-7
11,CC
12-1
12-2
12-3
12-4
12-5
12-6
12-7
12,CC
13-1
0 cm
25
50
75
100
125
150

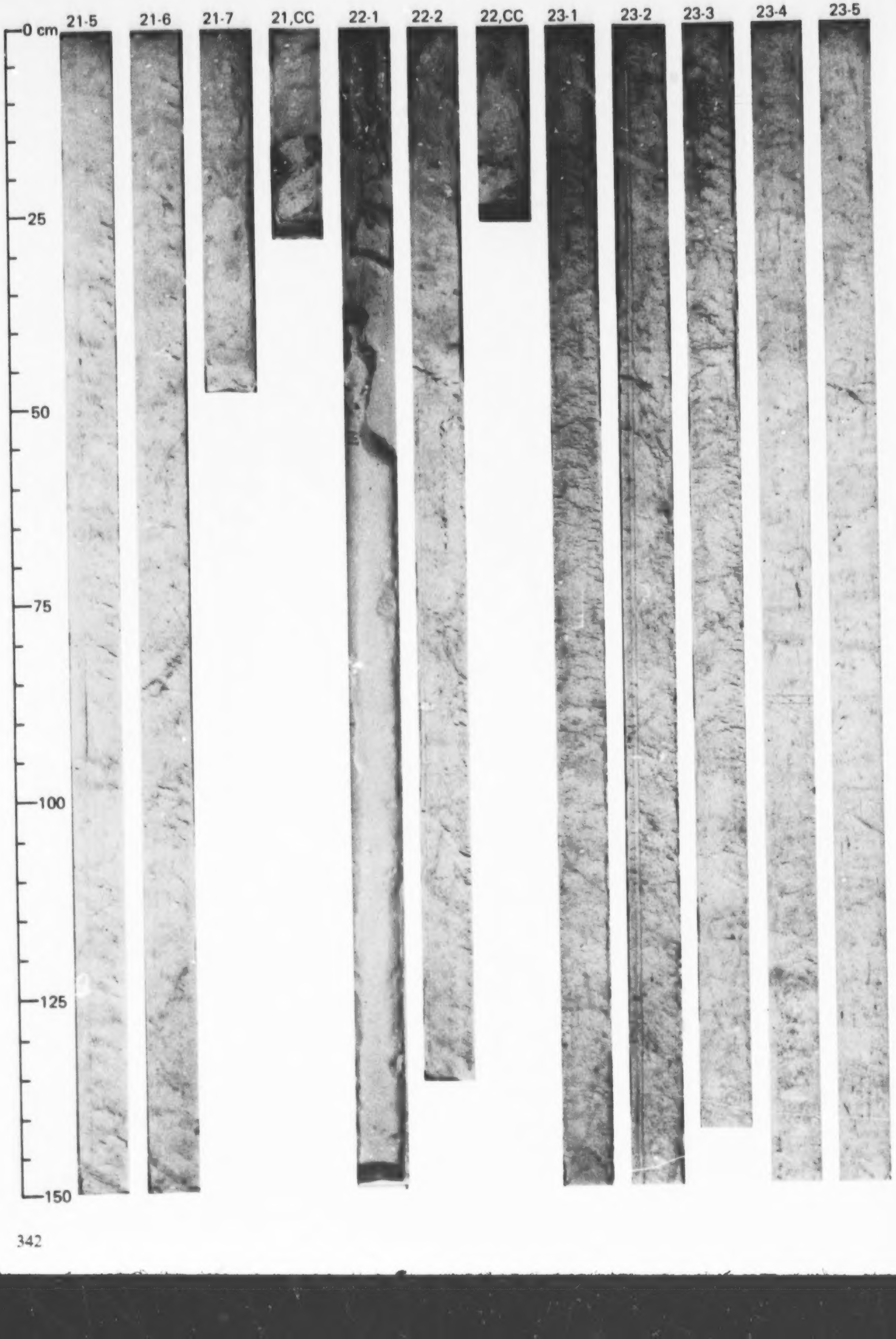

0 cm
25
50
75
100
125
150
13-2
13-3
13-4
13-5
13-6
13,CC
14-1
14-2
14-3
14-4
14-5
14-6

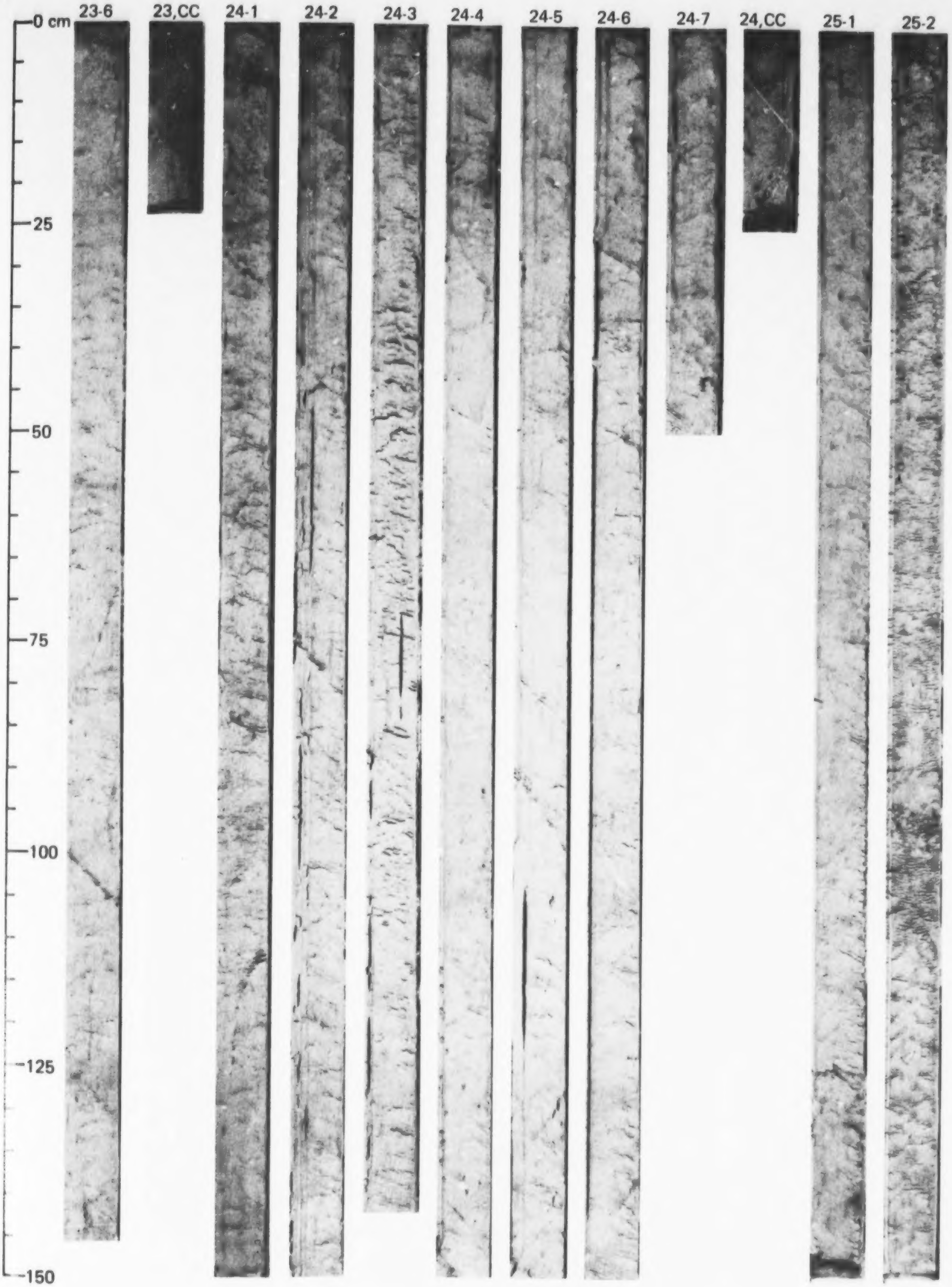

14-7
14,CC
15-1
15-2
15-3
15-4
15-5
15-6
15-7
15,CC
16-1
16-2
0 cm
25
50
75
100
125
150

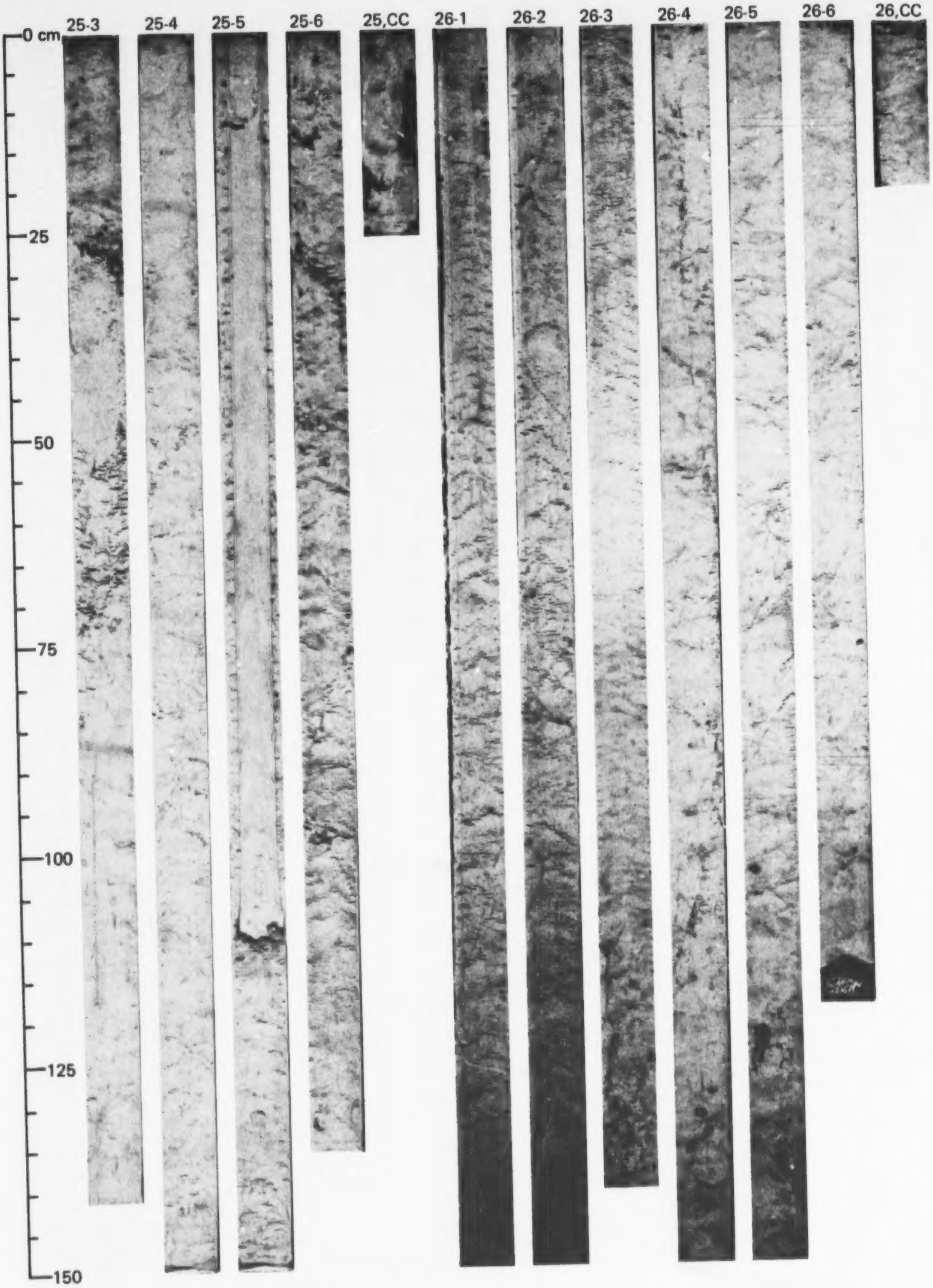

0 cm
25
50
75
100
125
150
16-3
16-4
16-5
16,CC
17-1
17-2
17-3
17-4
17-5
17-6
17,CC
18-1


18-2
18-3
18-4
18-5
18-6
18.CC
19-1
19-2
19-3
19-4
19-5
19-6
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
19,CC
20-1
20-2
20-3
20-4
20-5
20-6
20,CC
21-1
21-2
21-3
21-4


21-5
21-6
21-7
21,CC
22-1
22-2
22,CC
23-1
23-2
23-3
23-4
23-5
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
23-6
23,CC
24-1
24-2
24-3
24-4
24-5
24-6
24-7
24,CC
25-1
25-2


25-3
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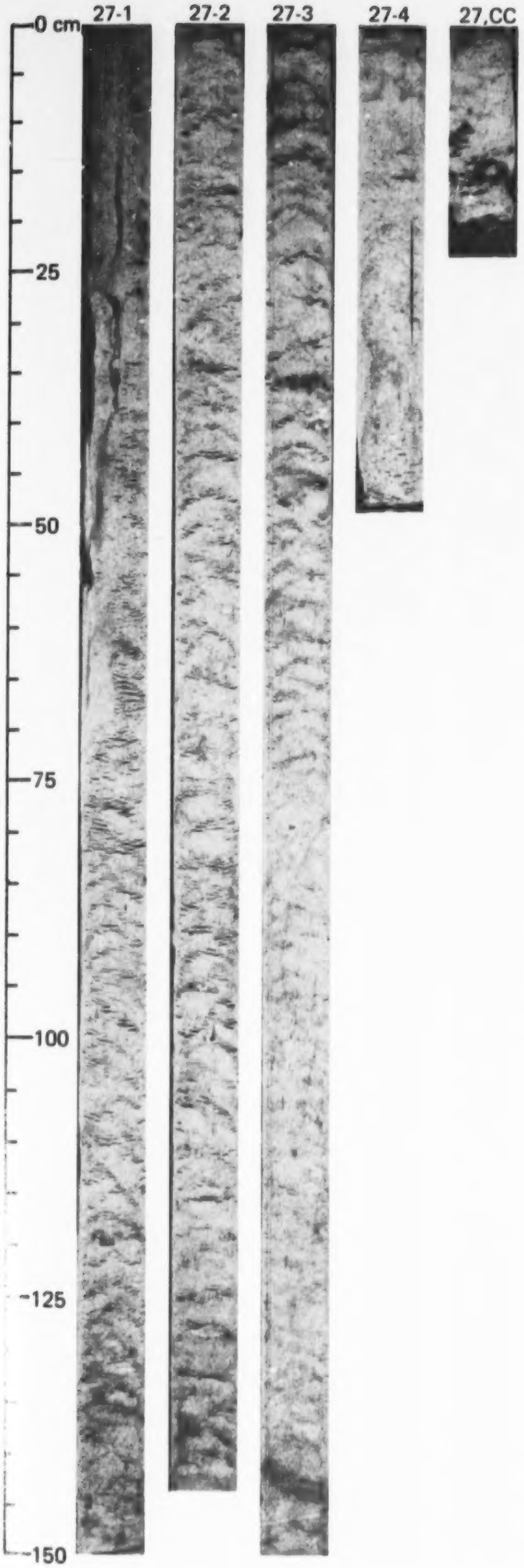
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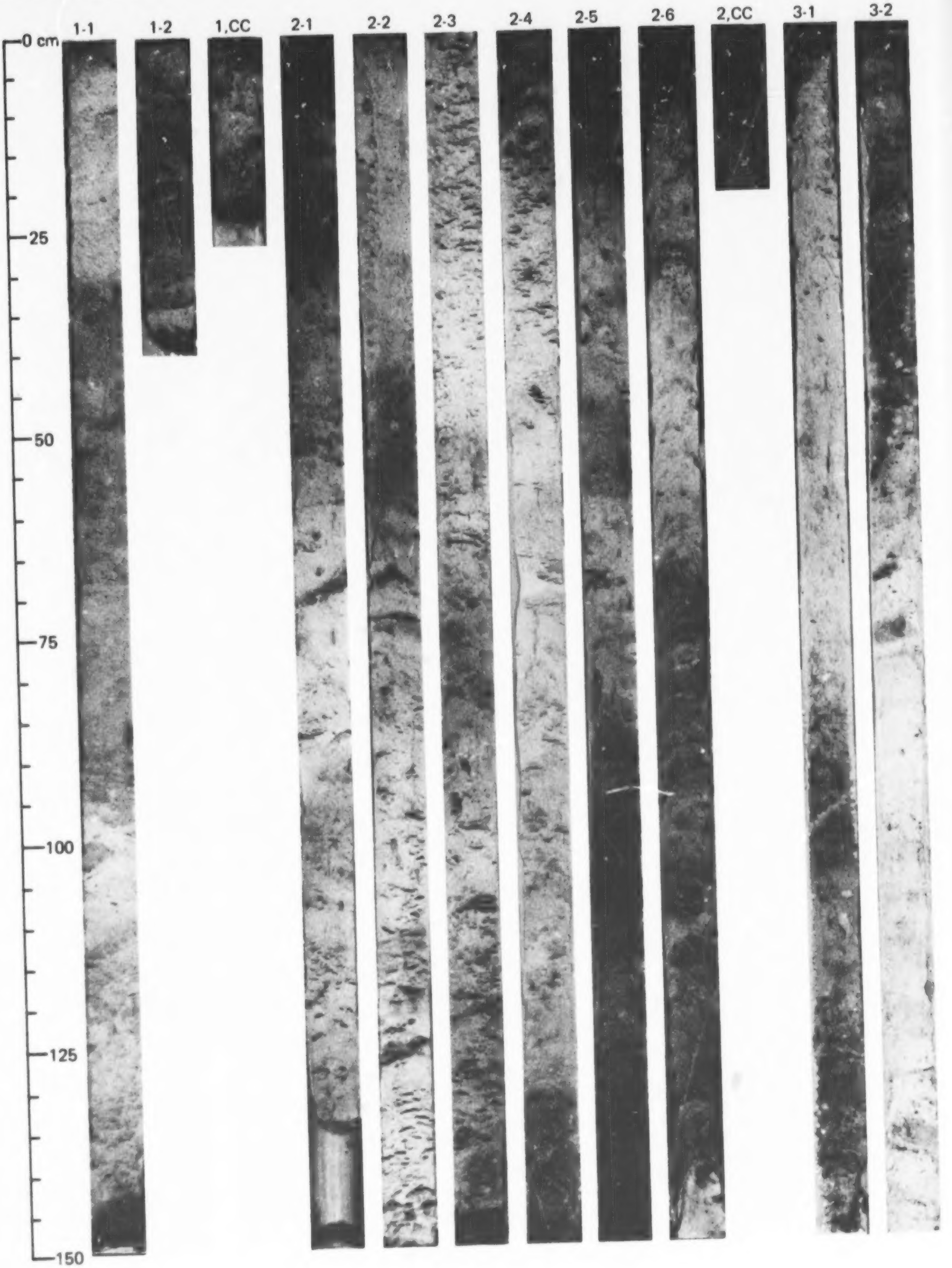
SITE 590 (HOLE 590B)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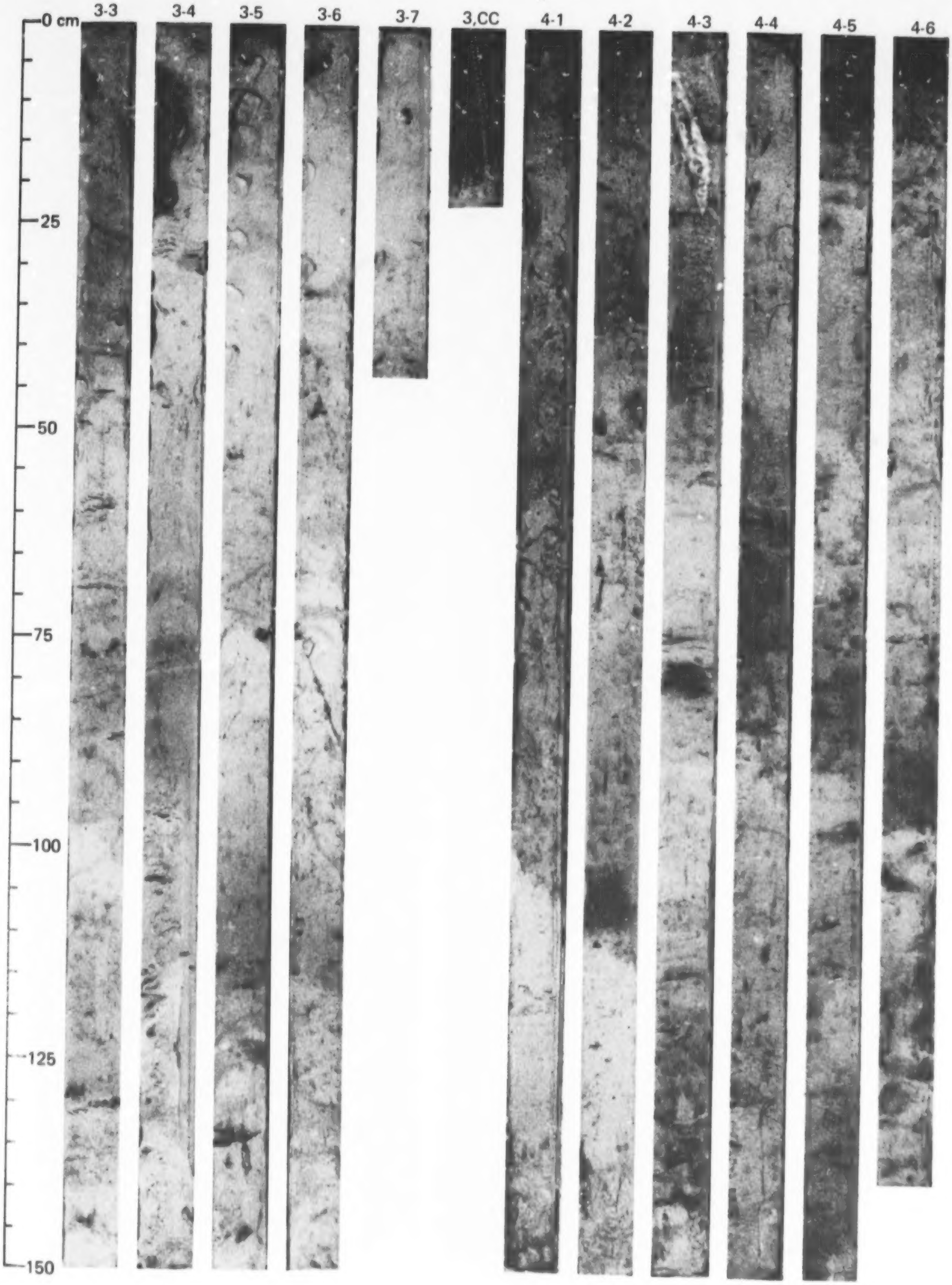
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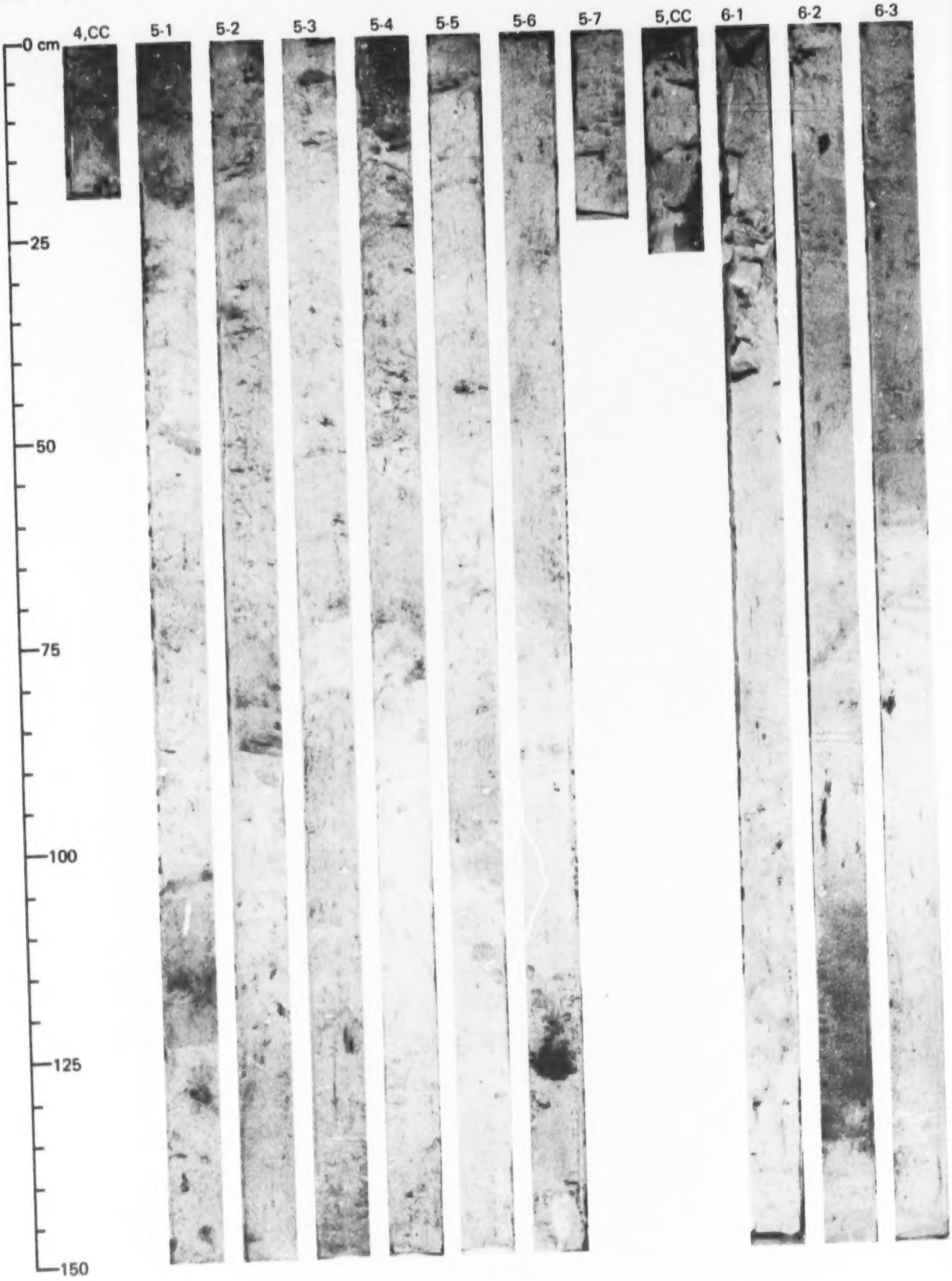
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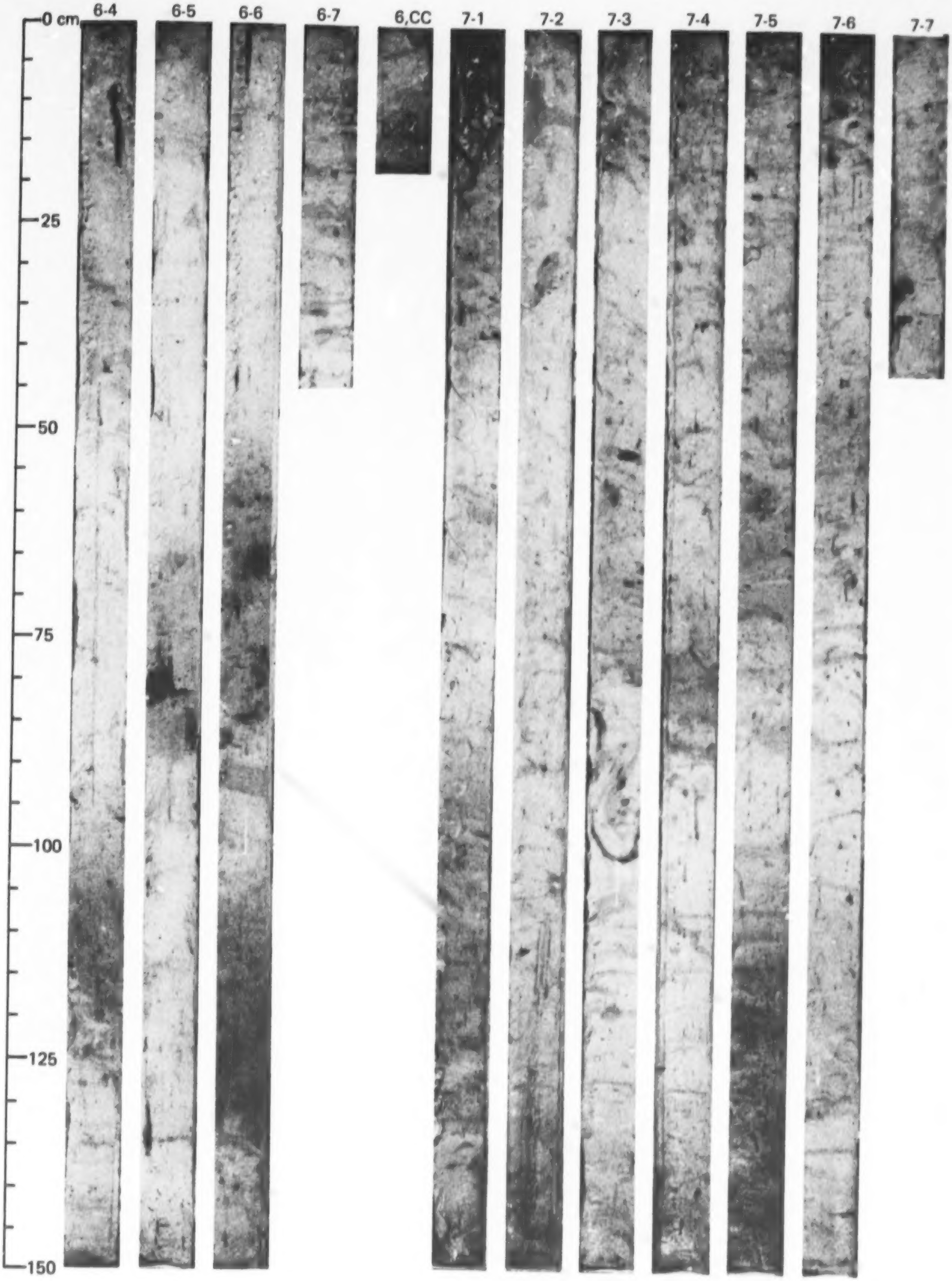
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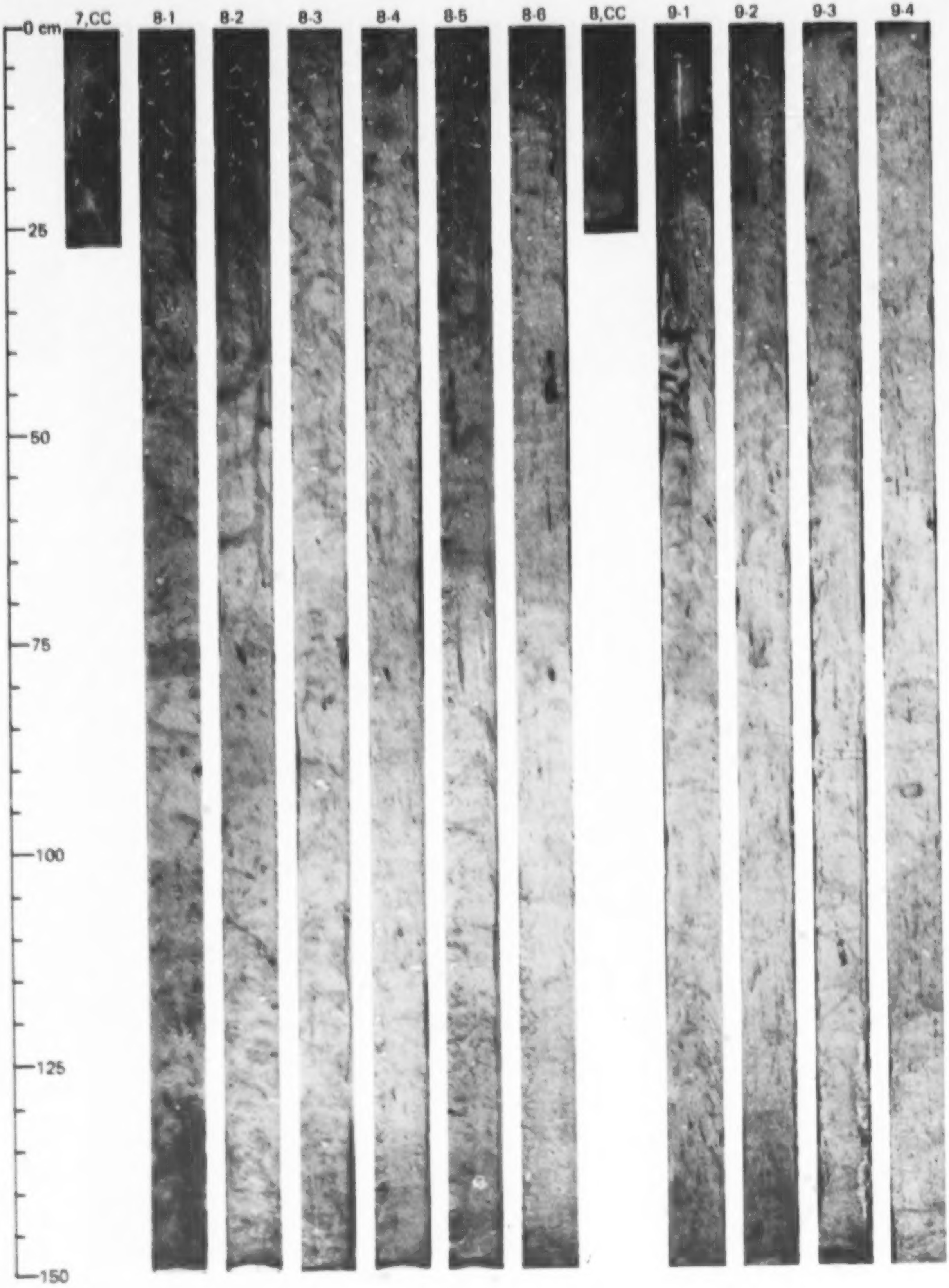
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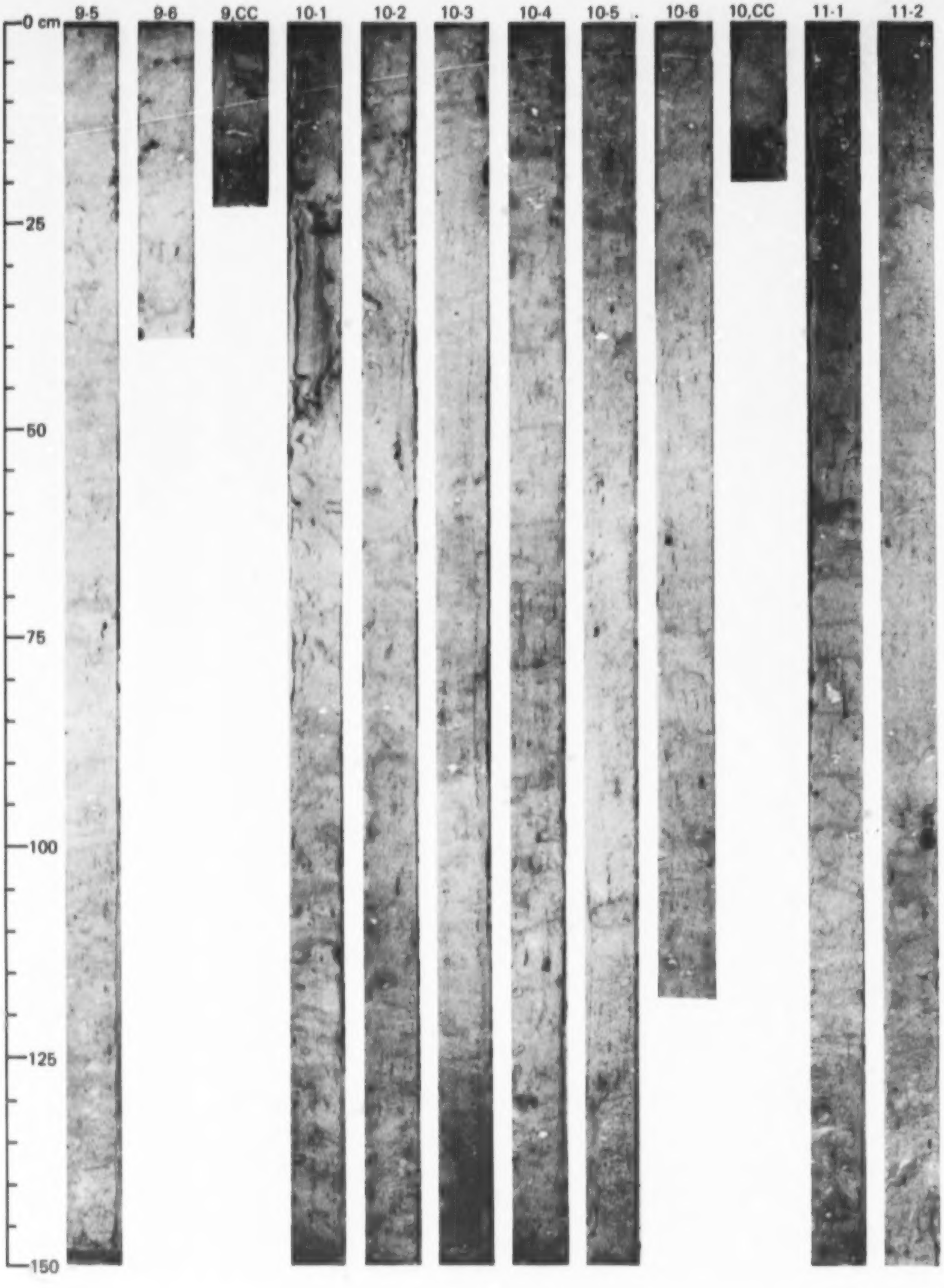
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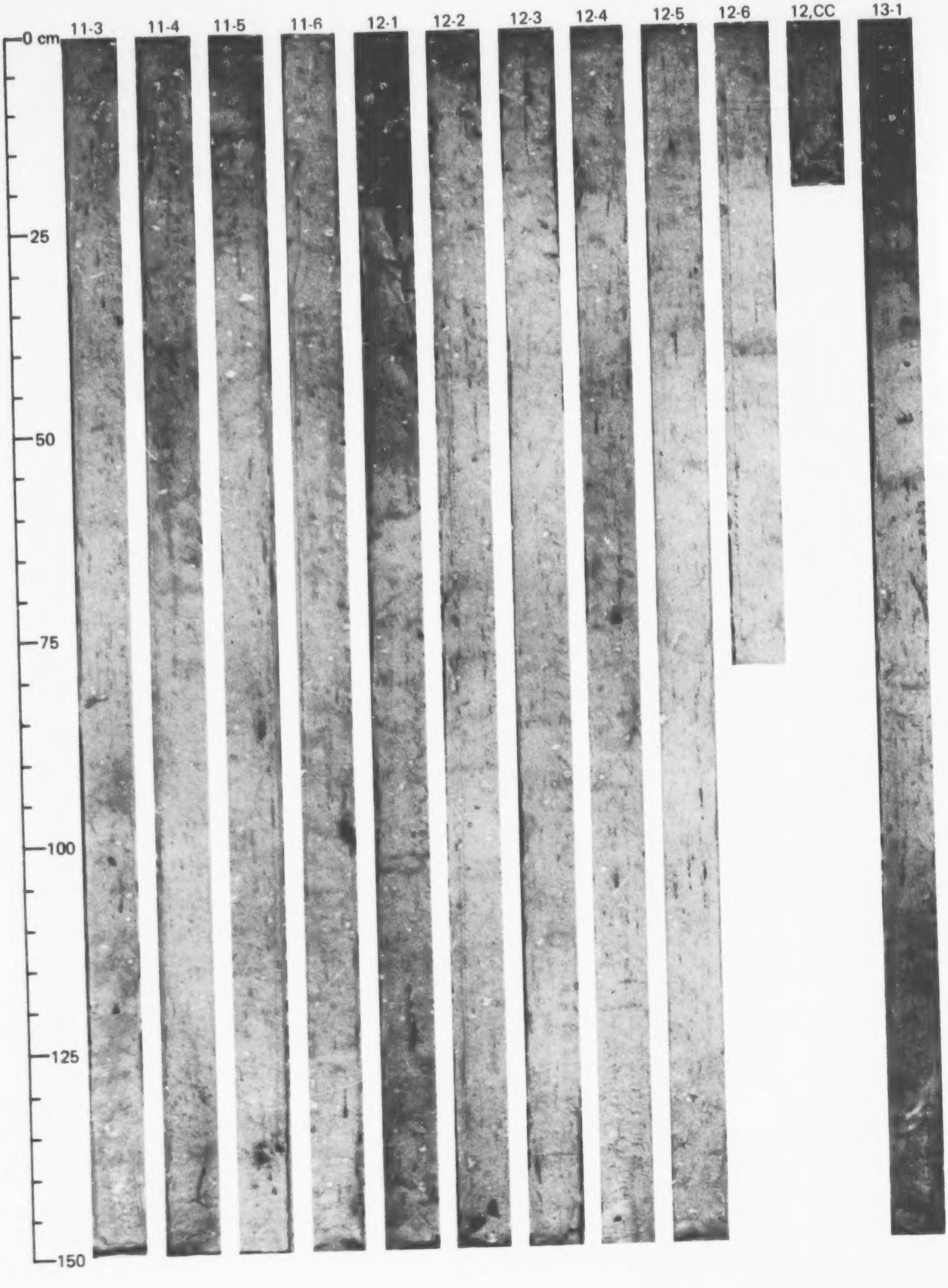
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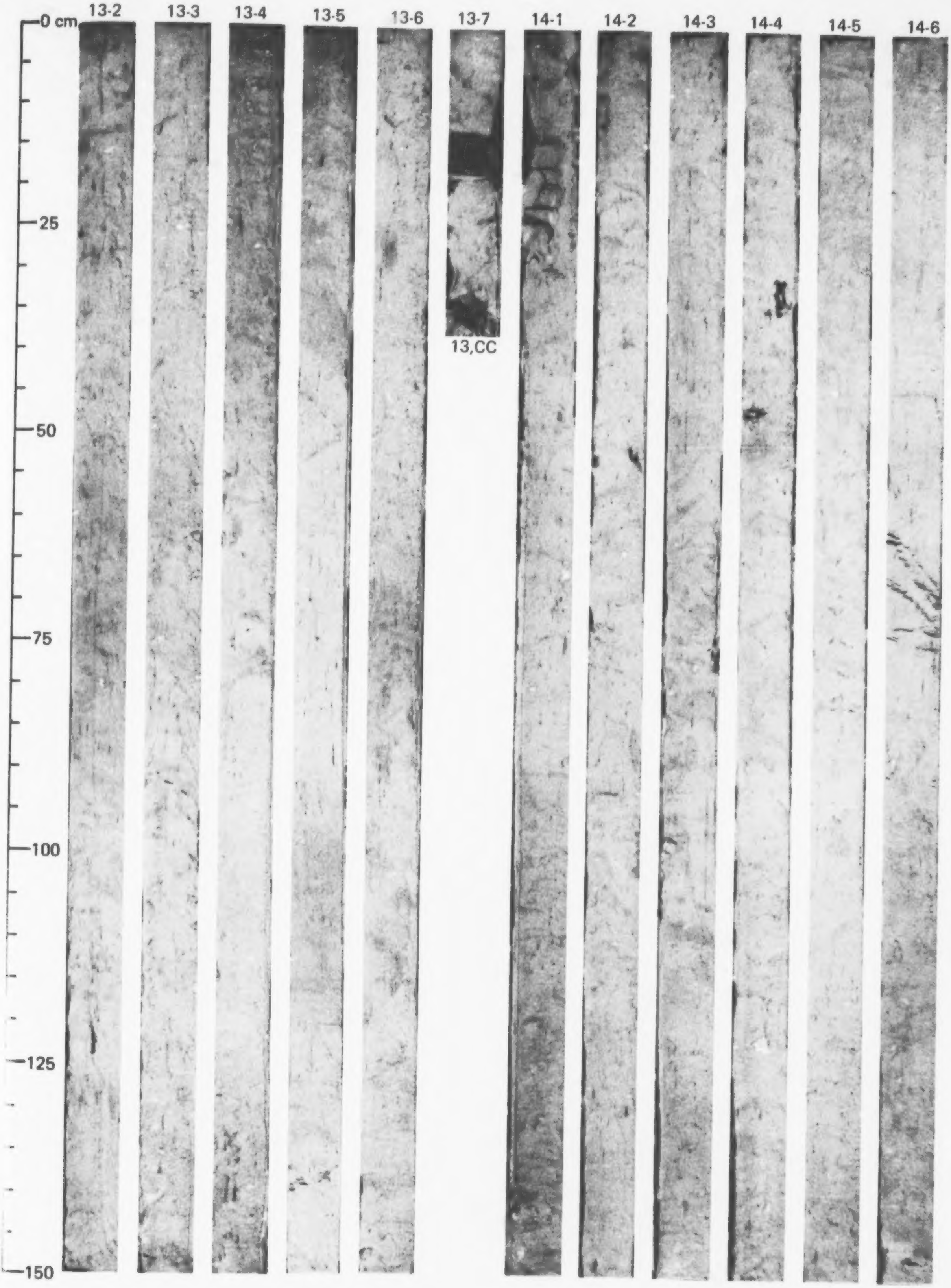
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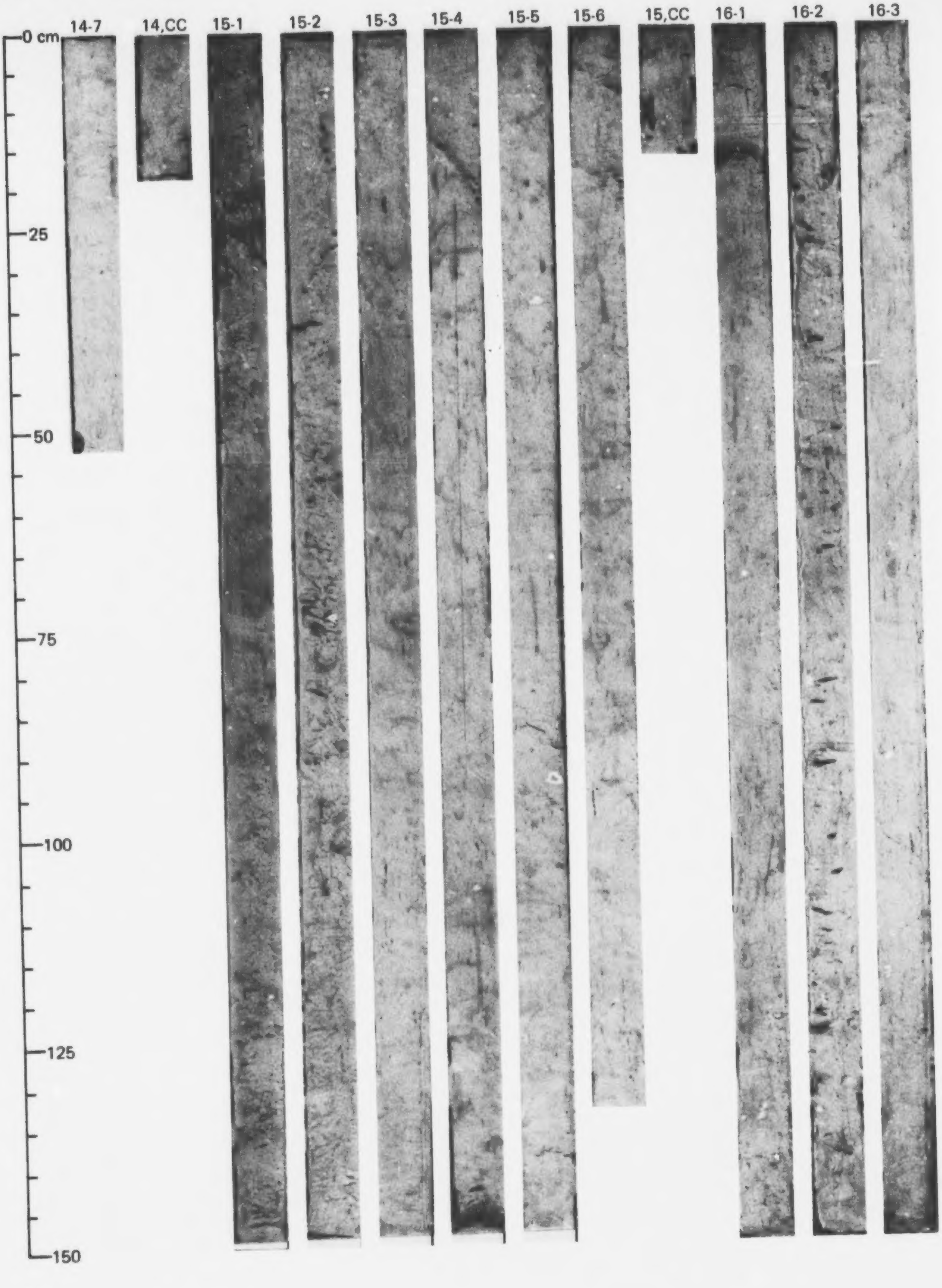
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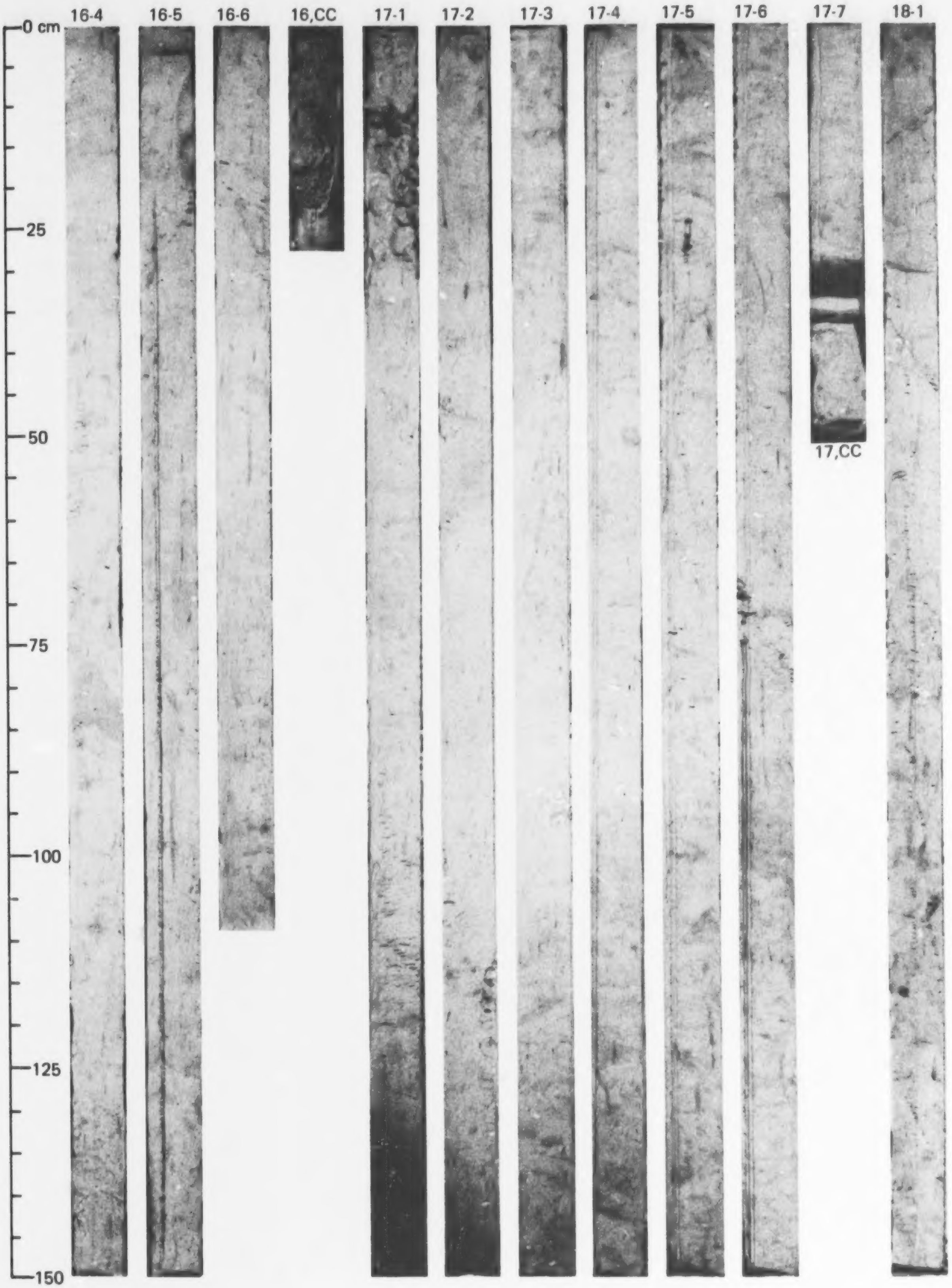
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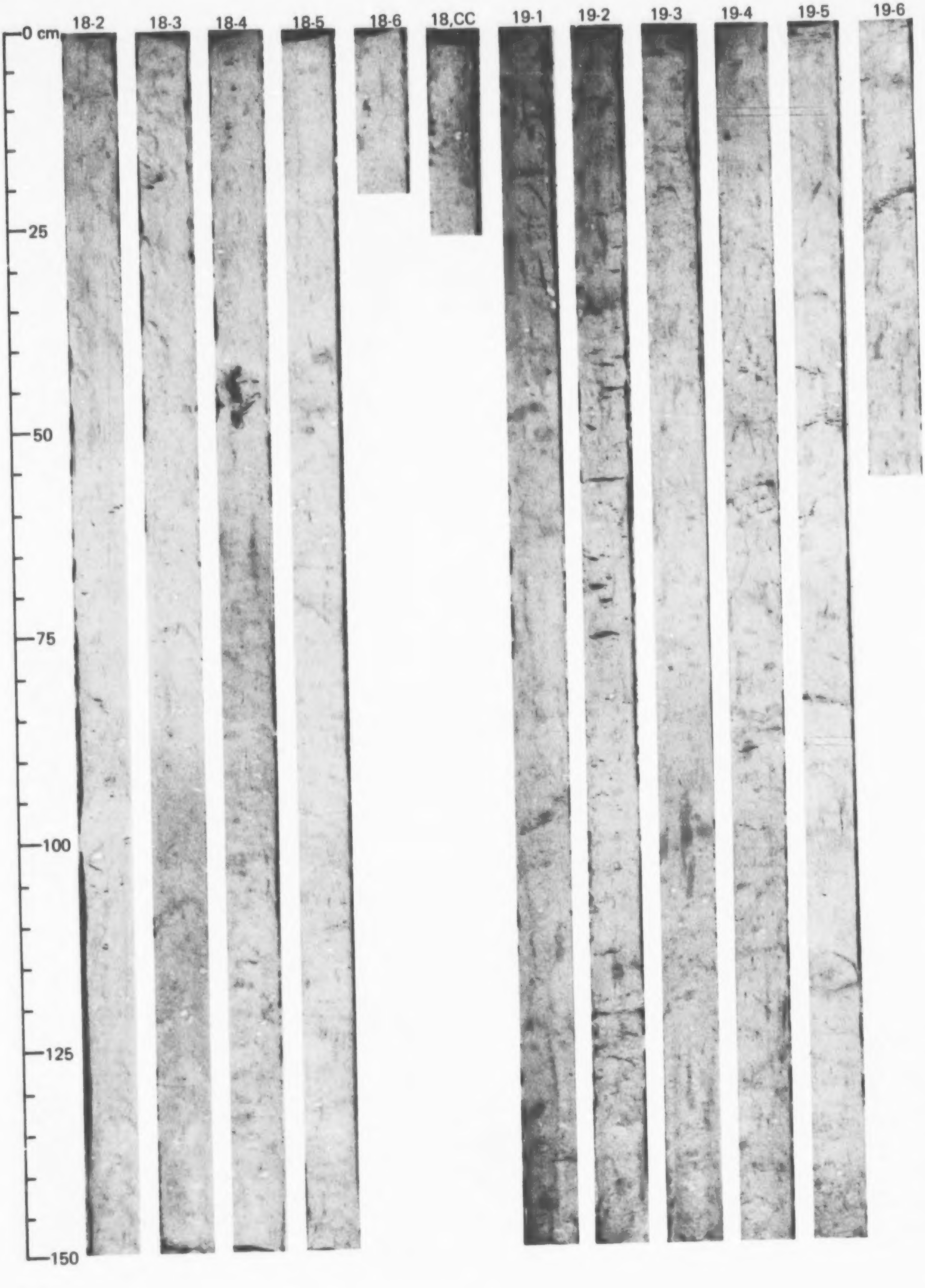
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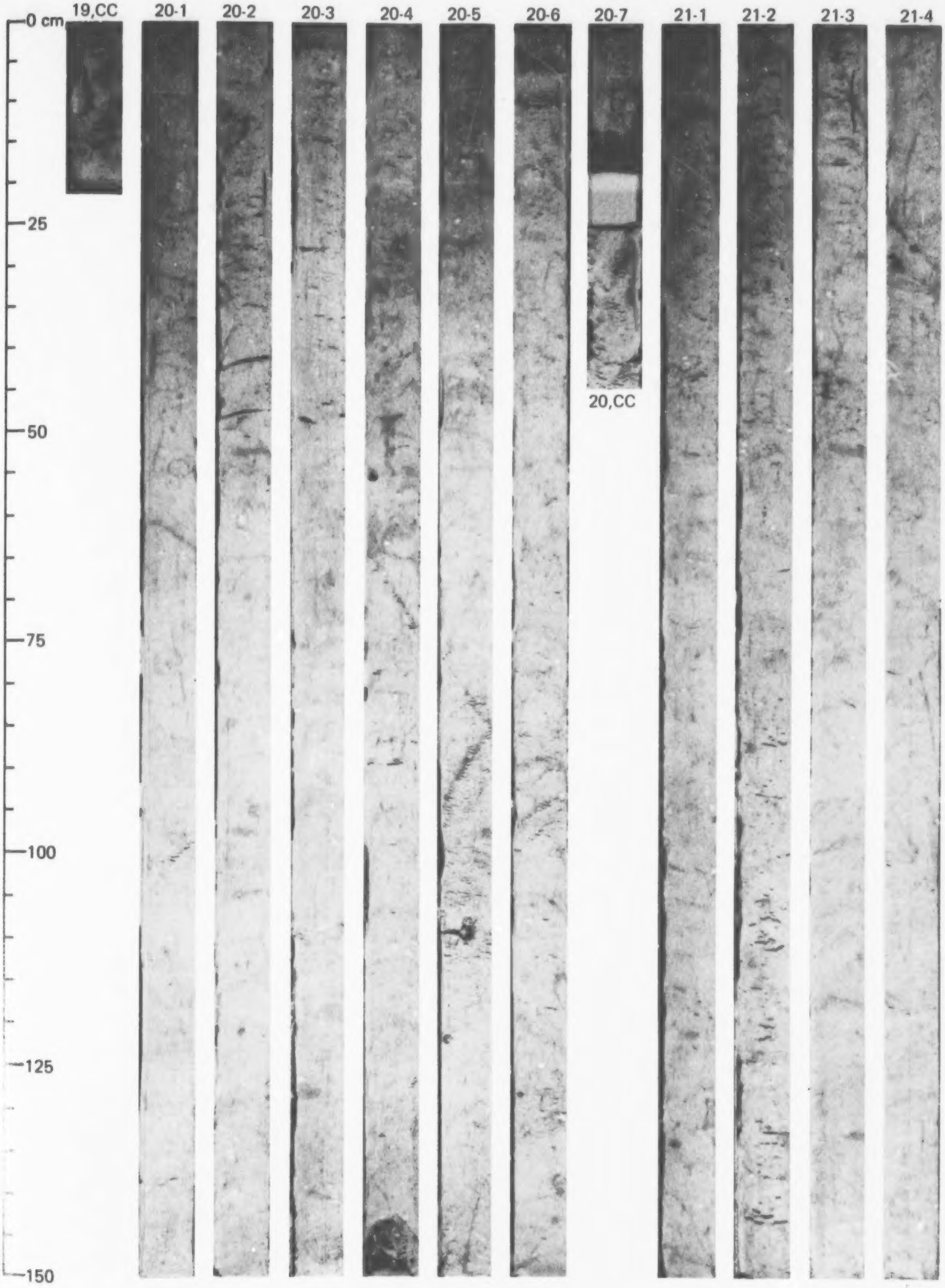
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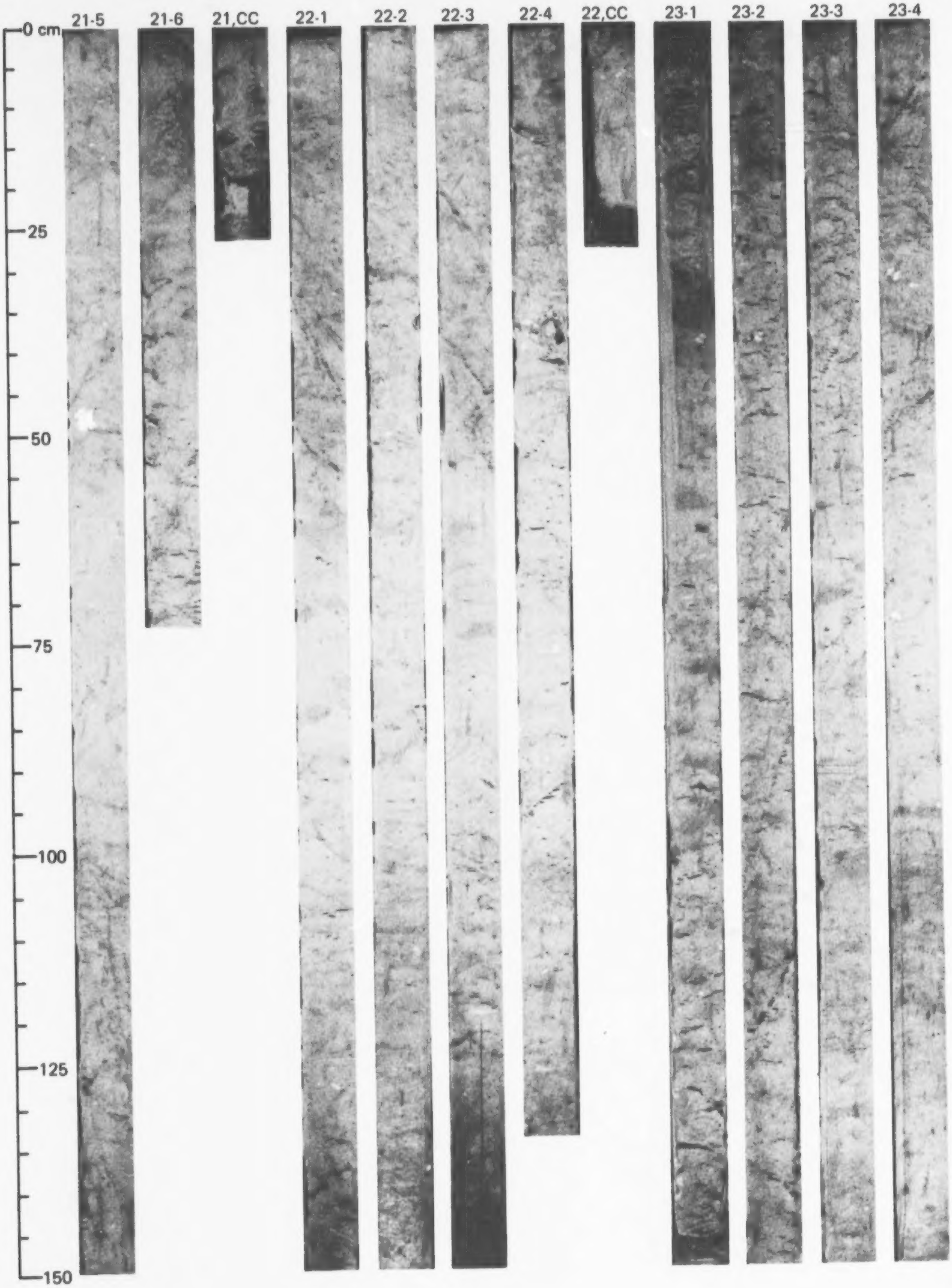
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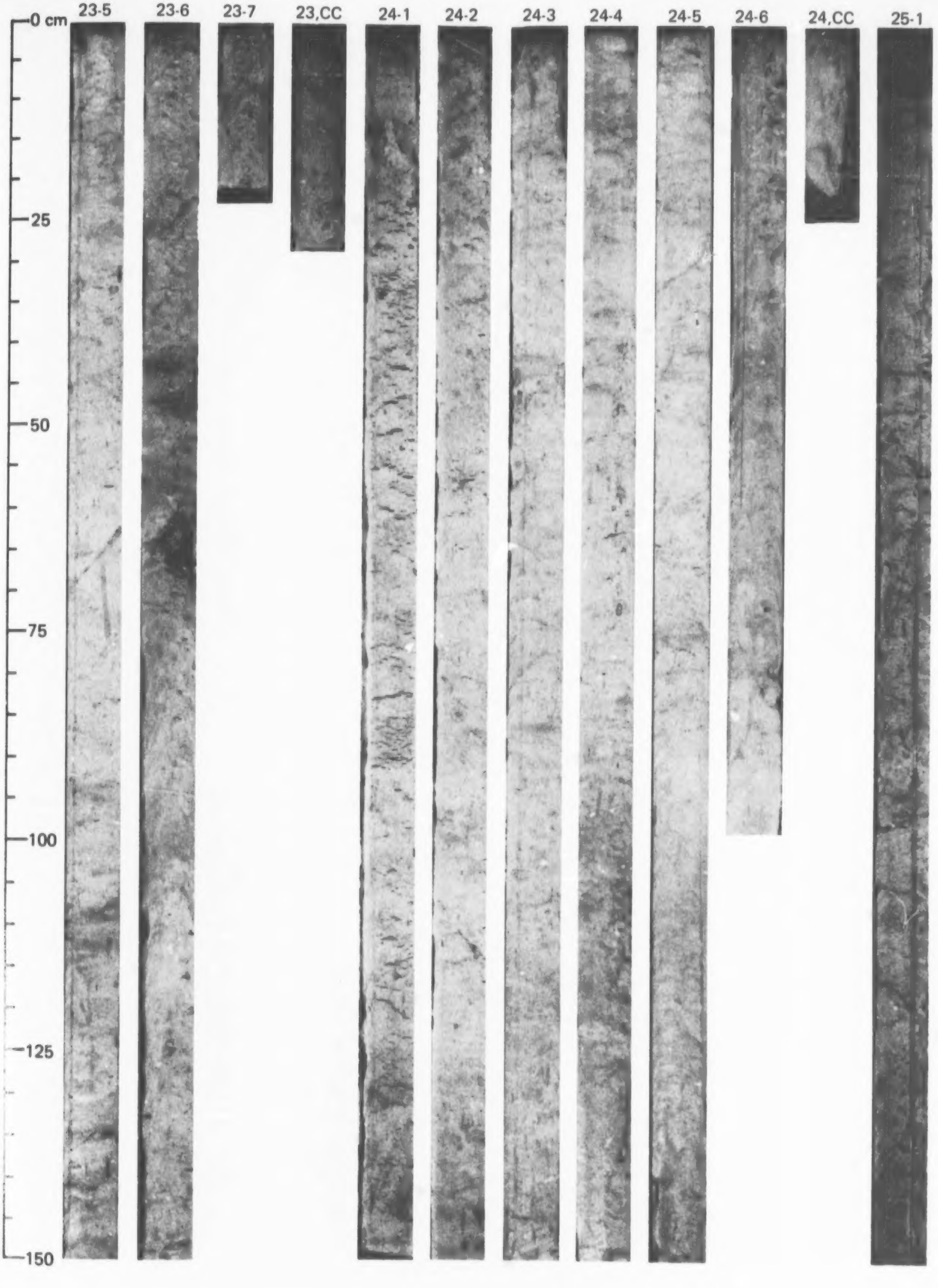
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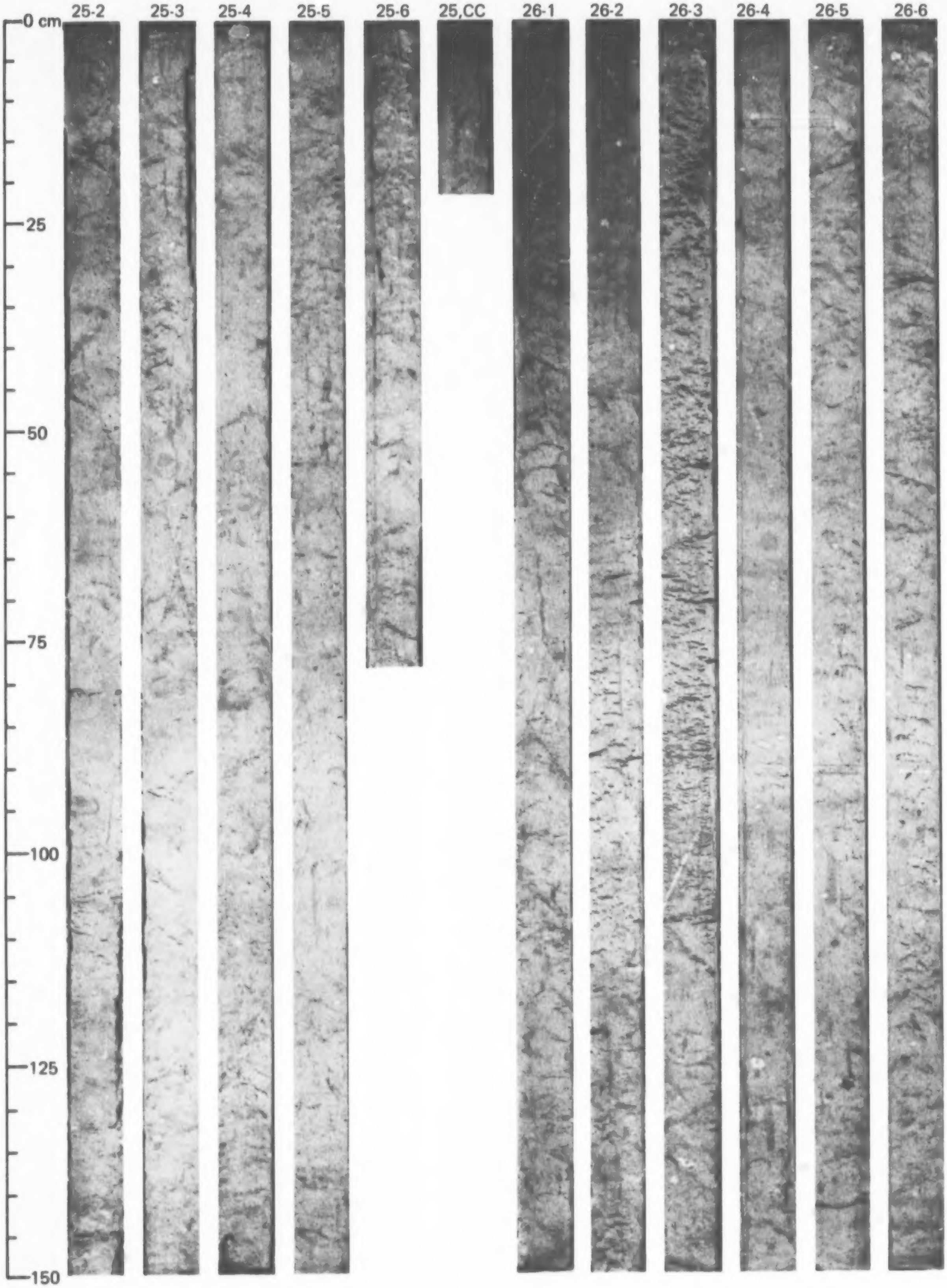
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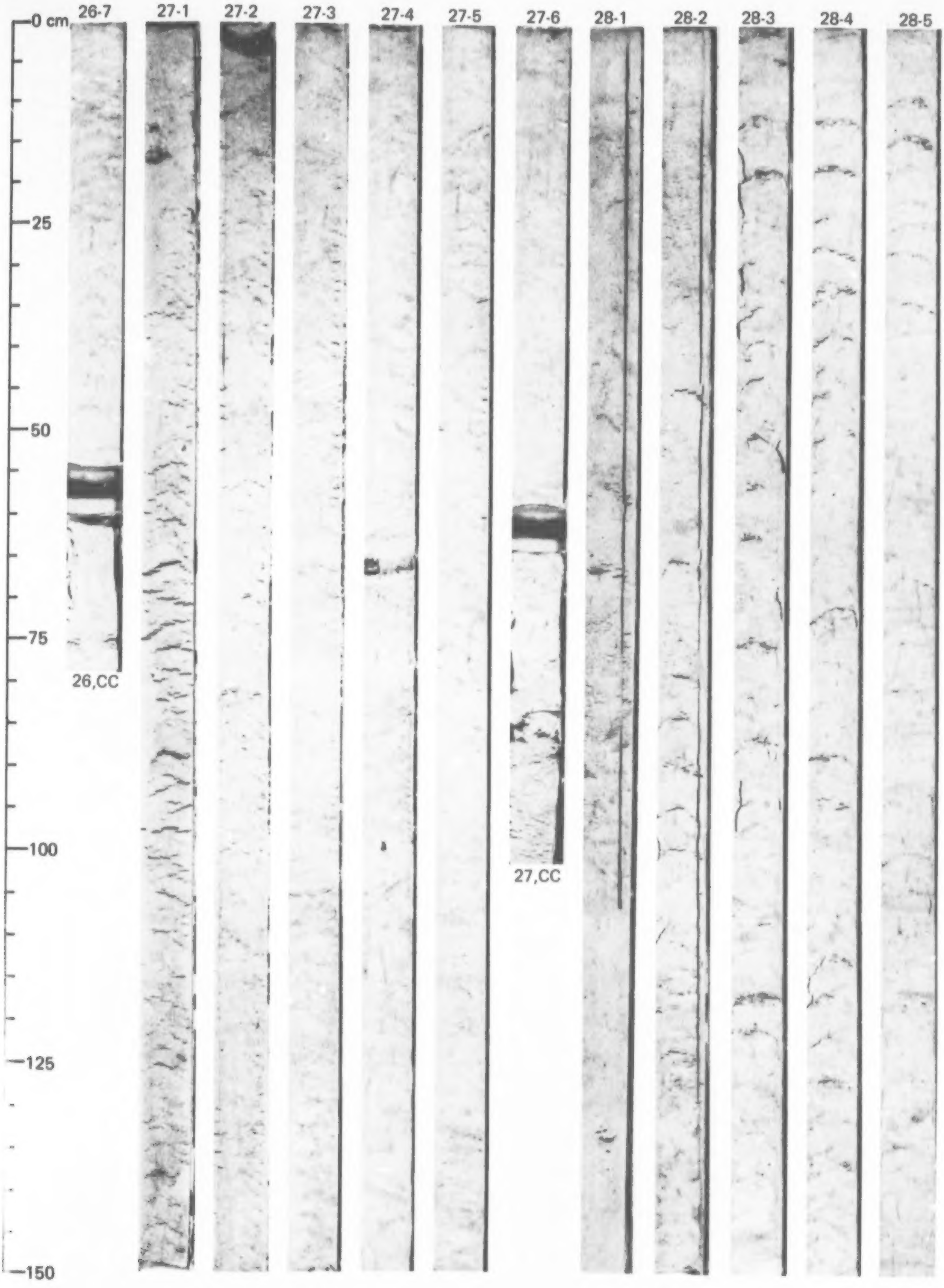
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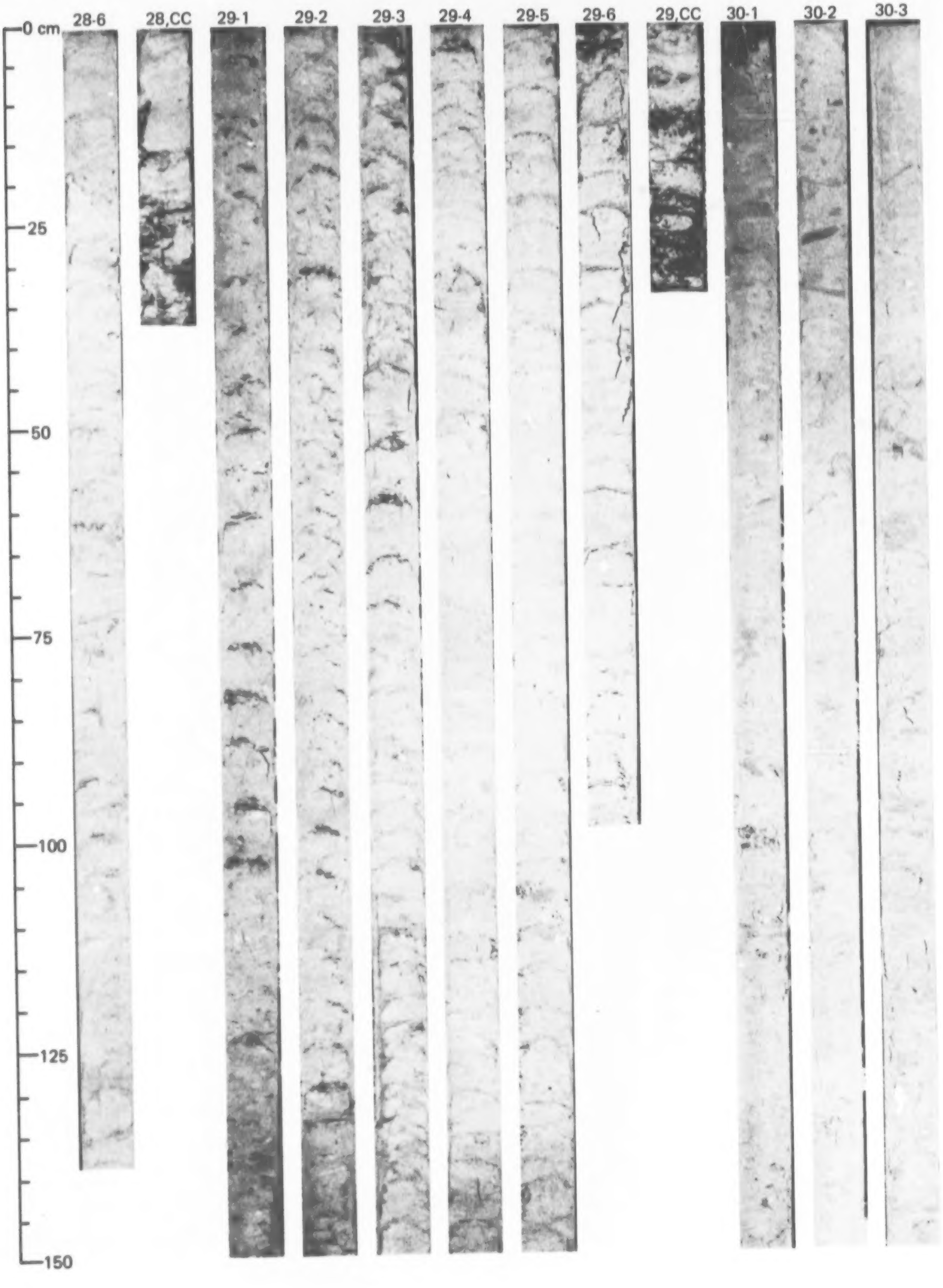
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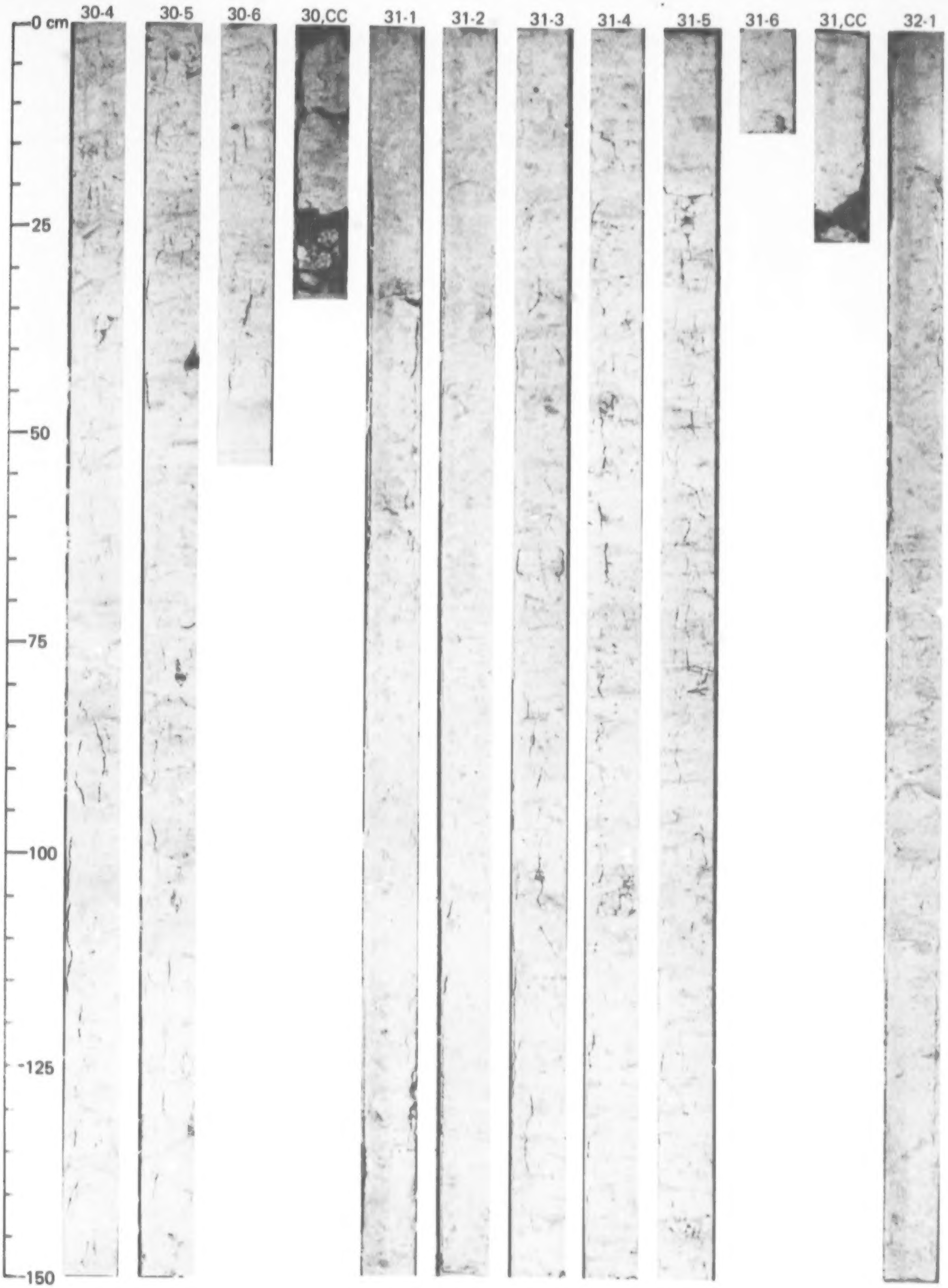
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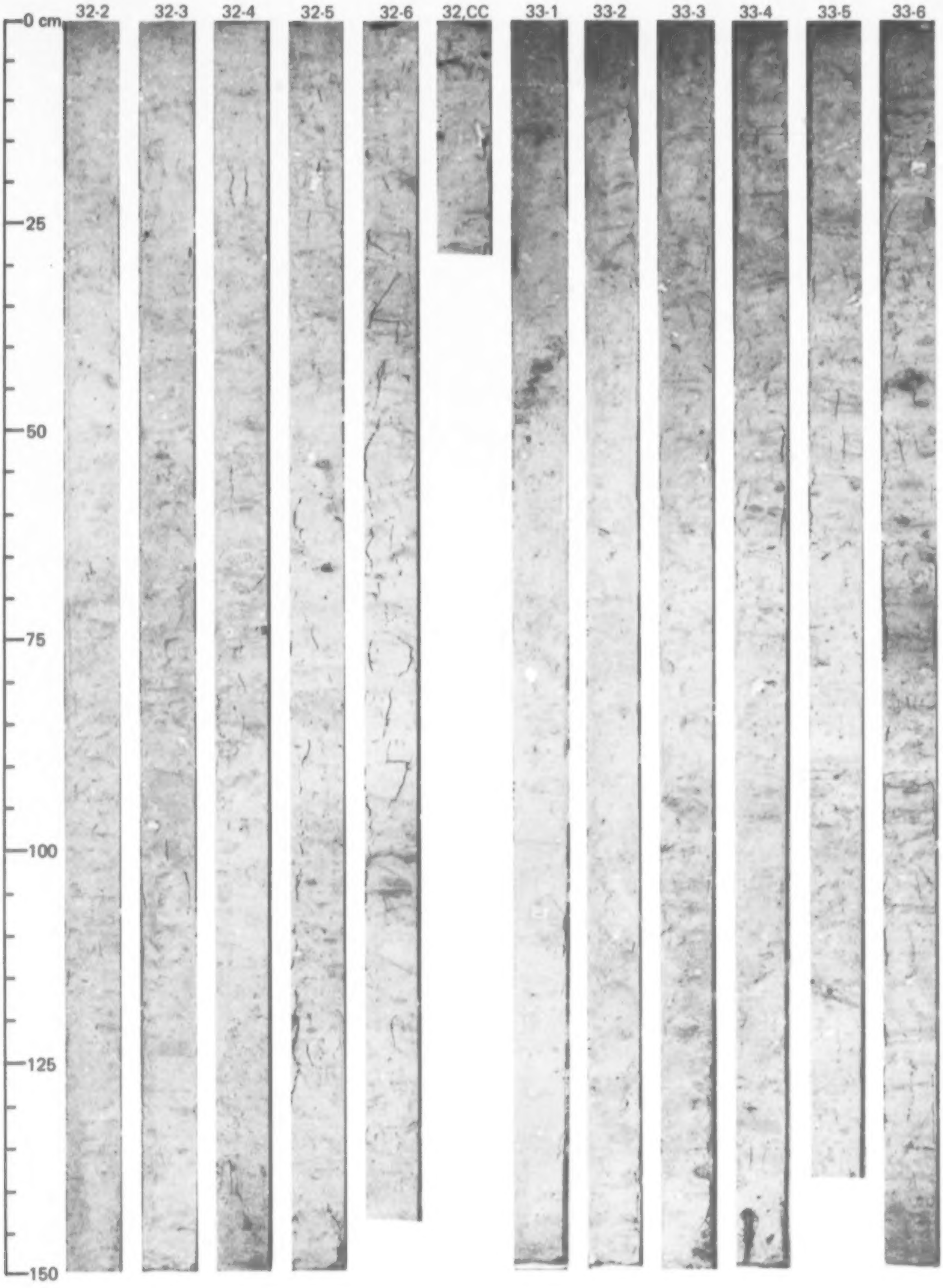
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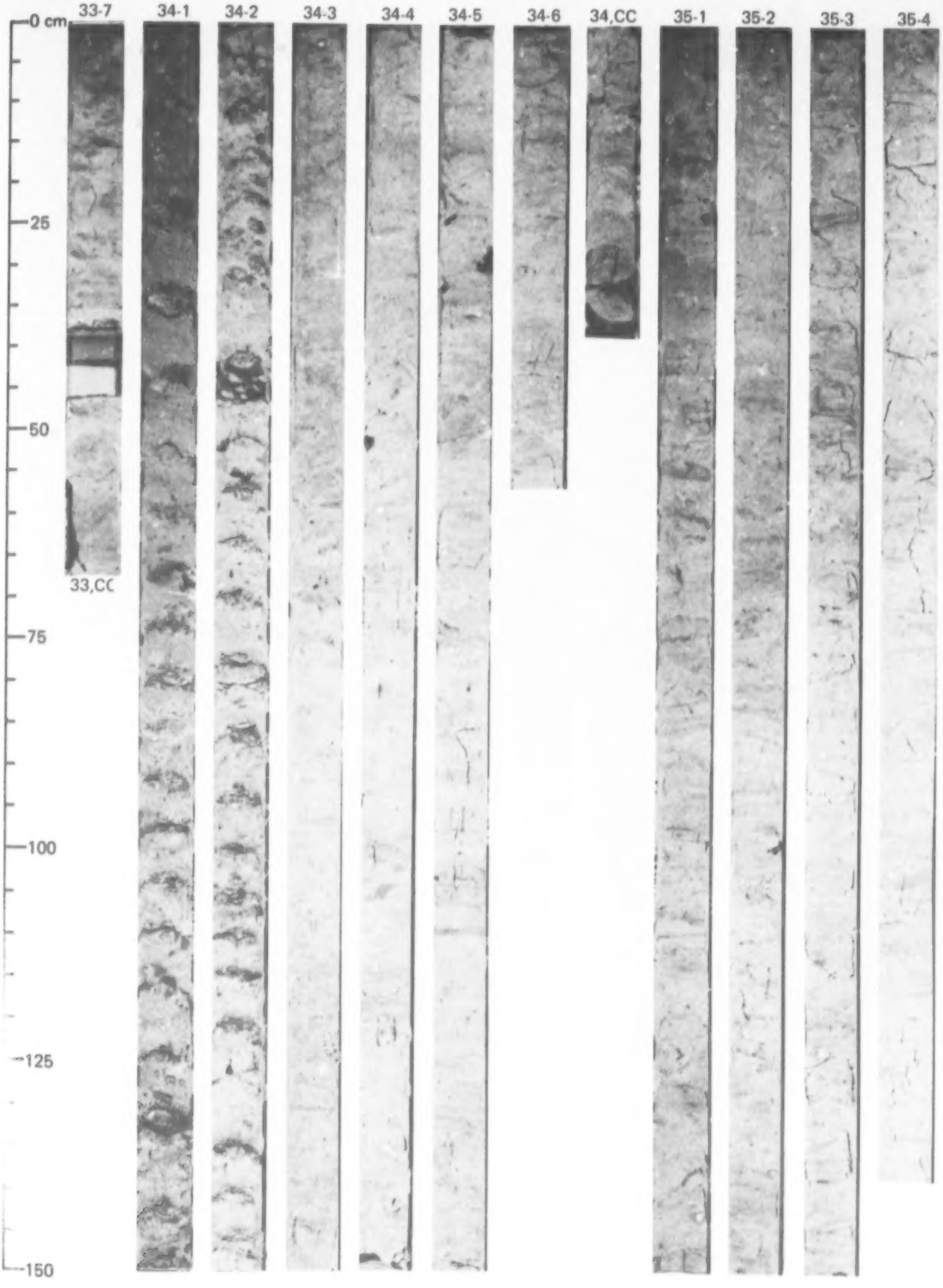
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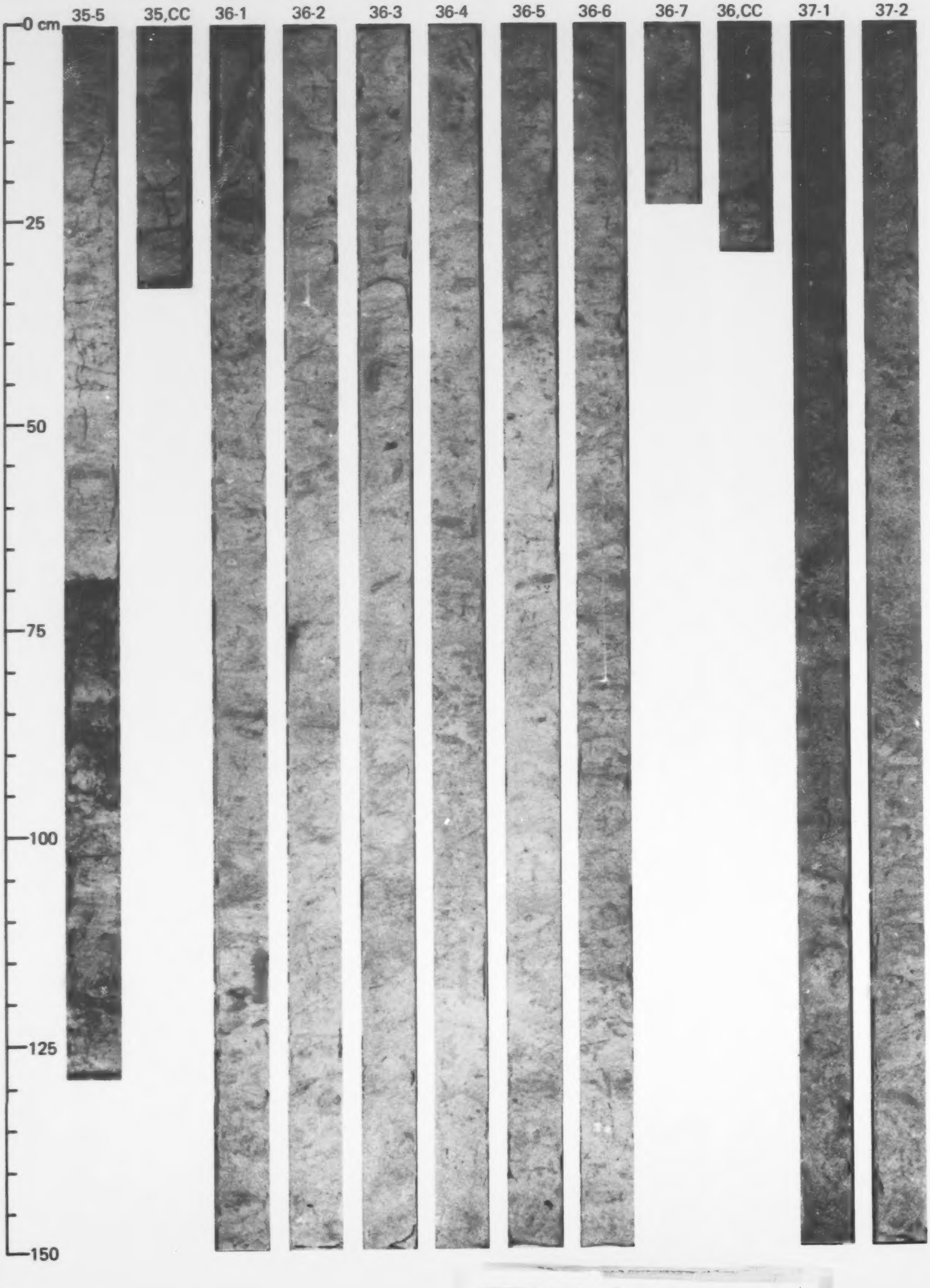
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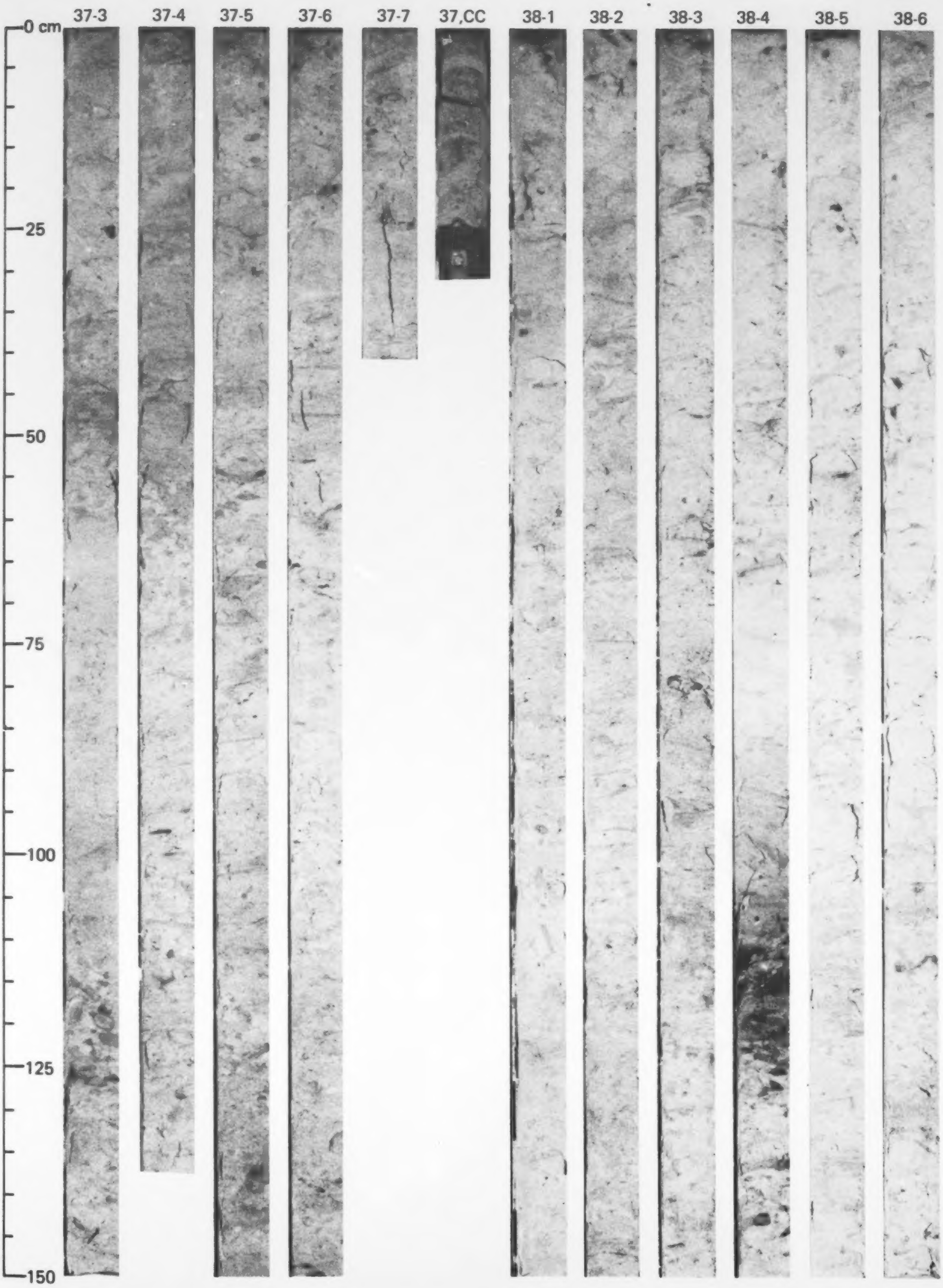
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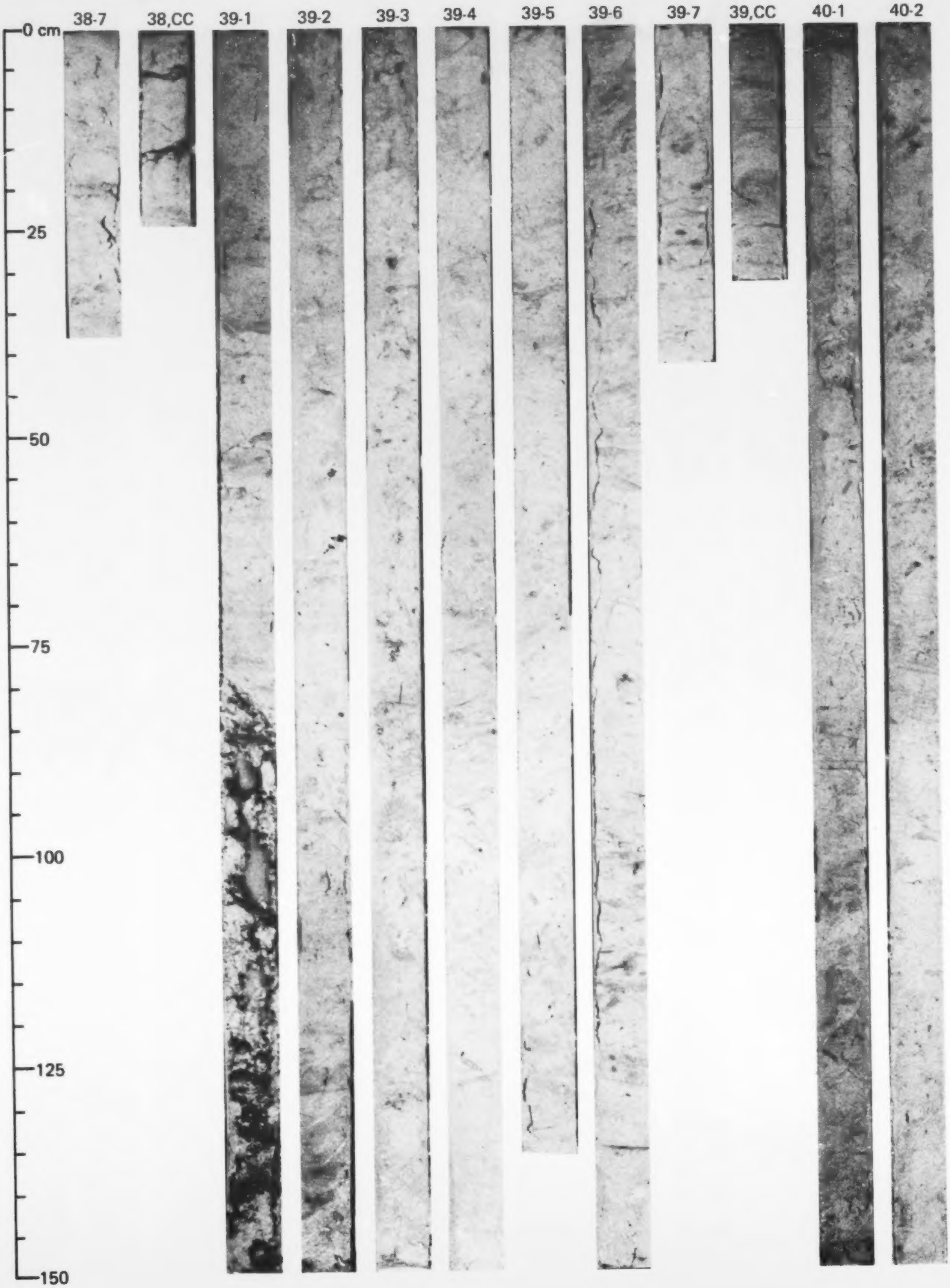
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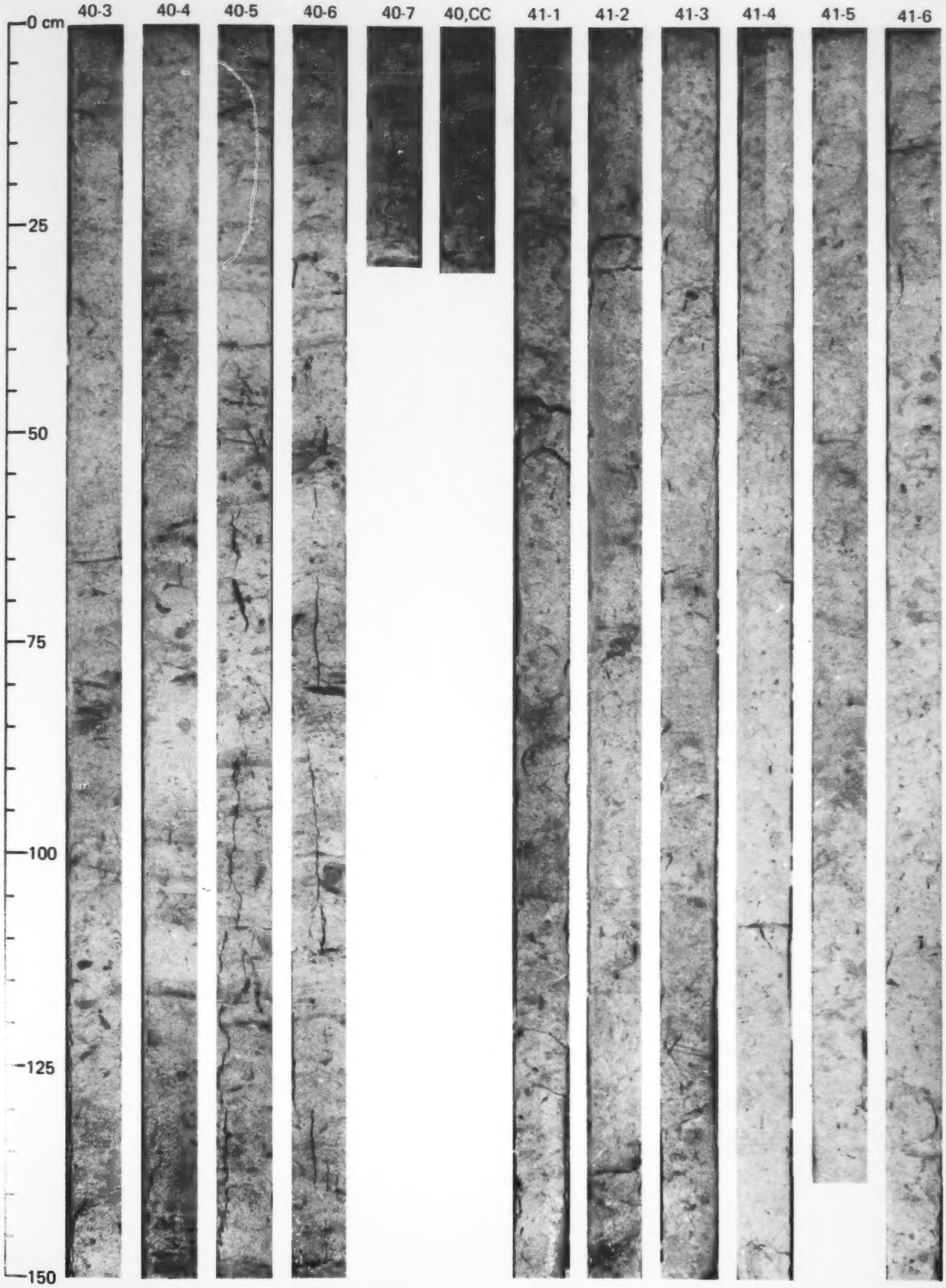

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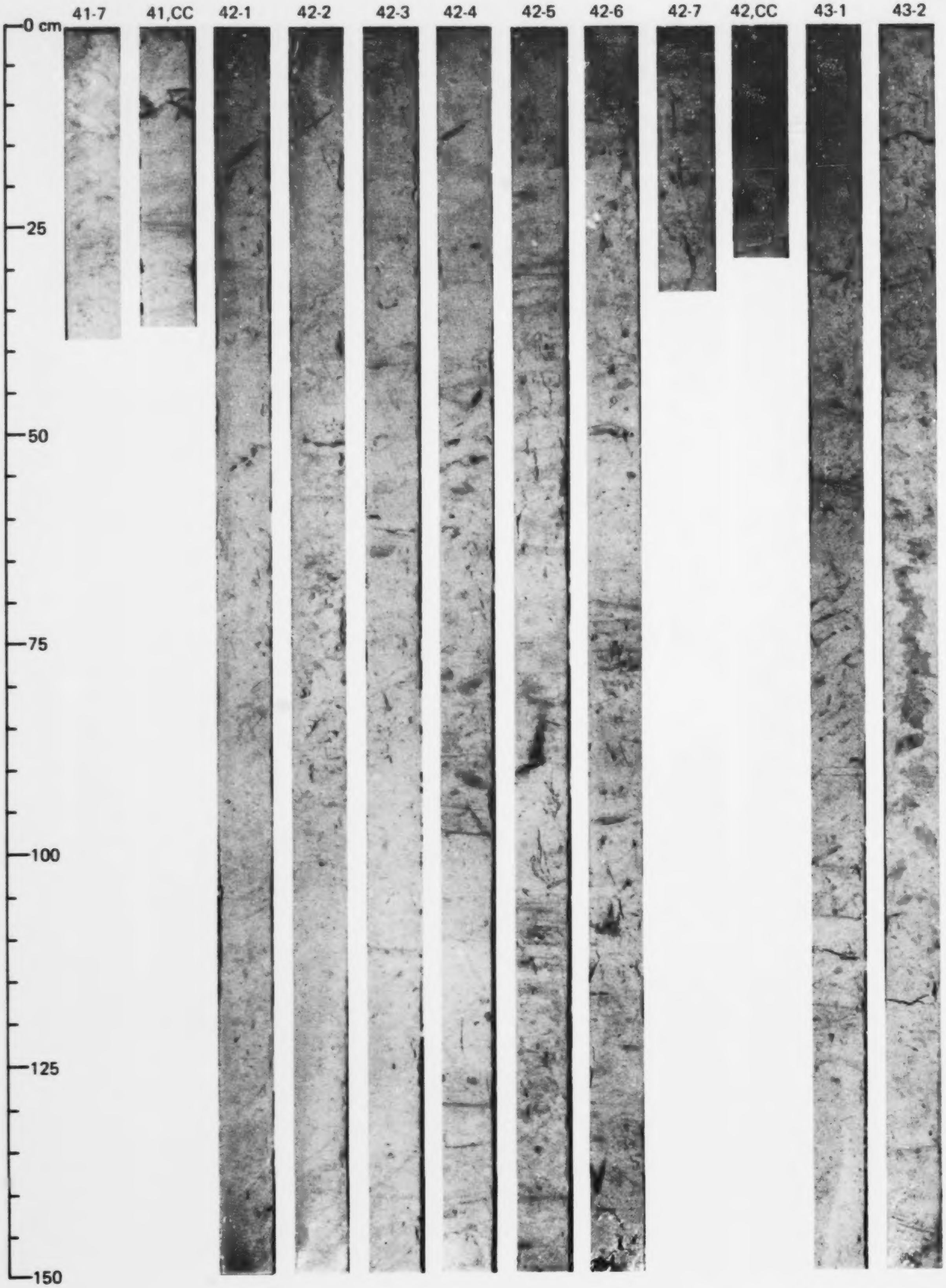
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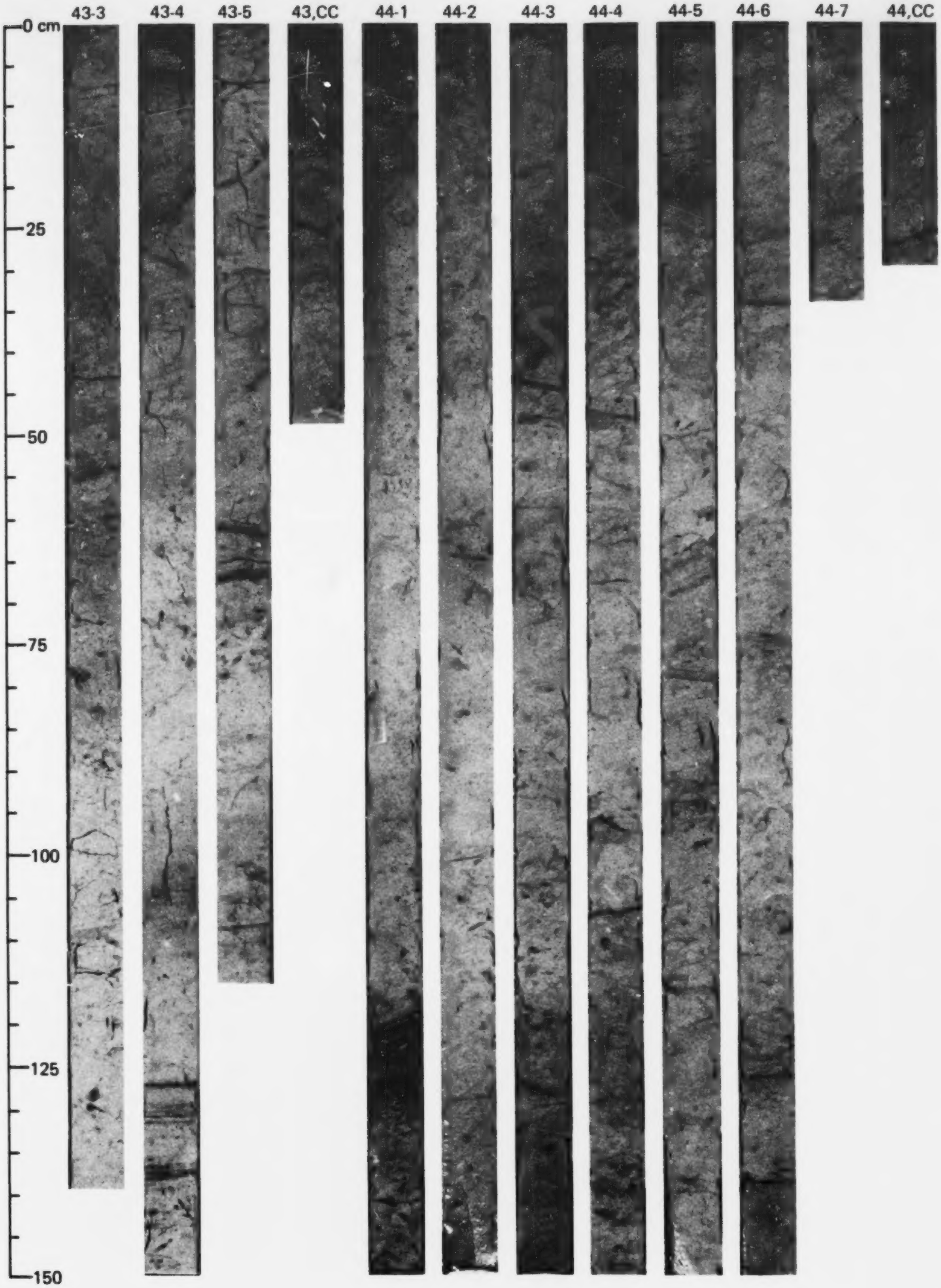
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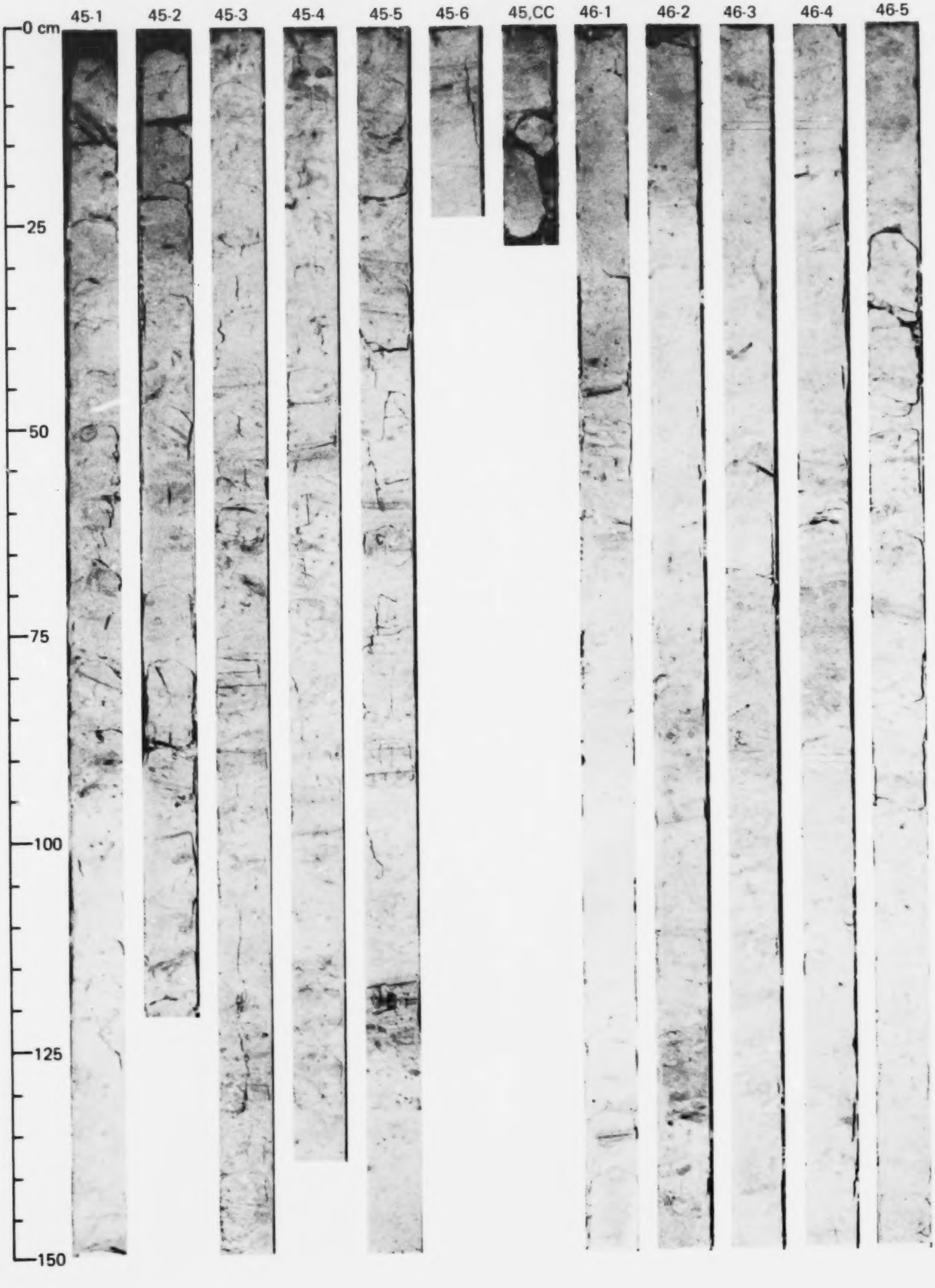
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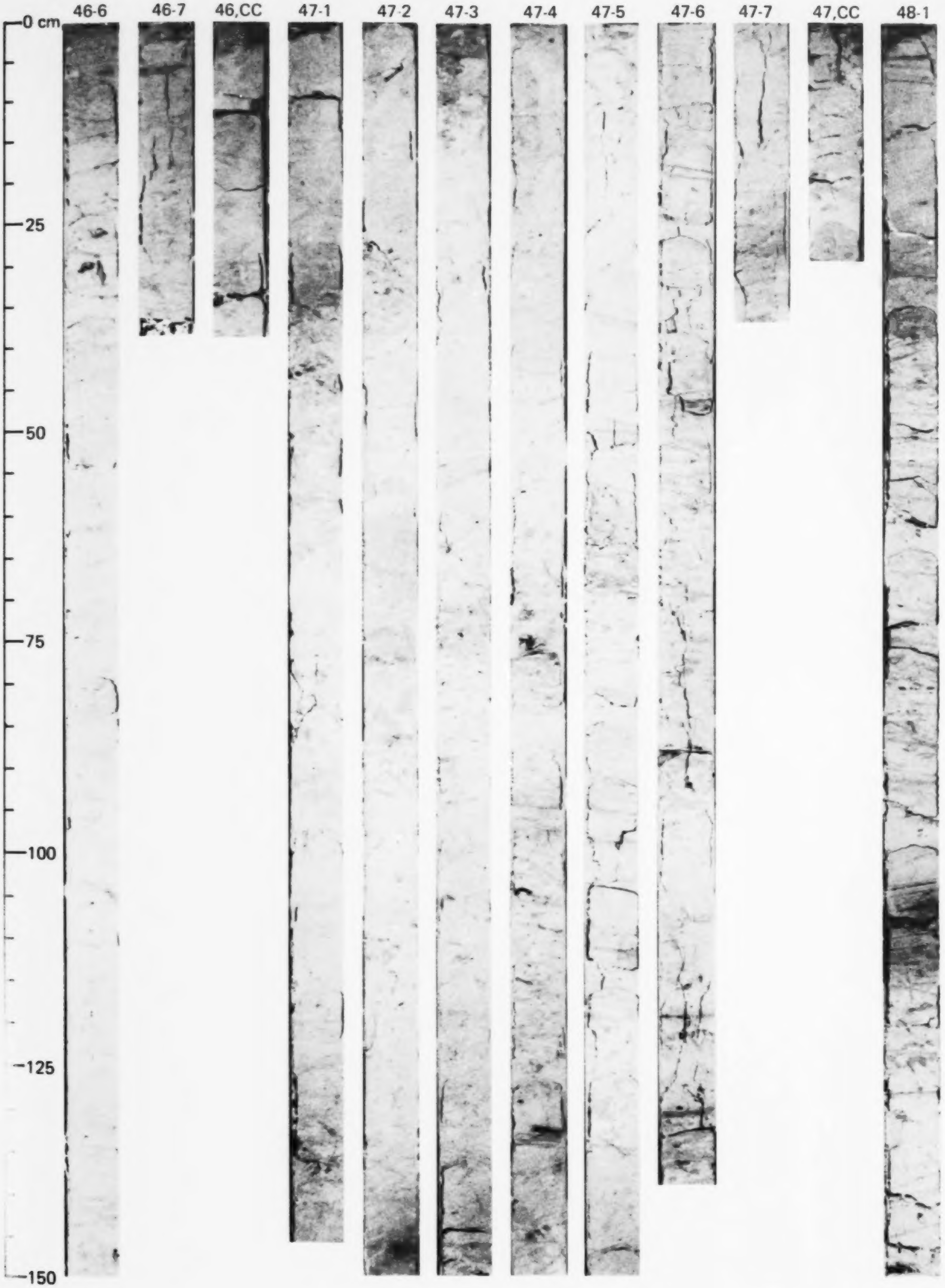
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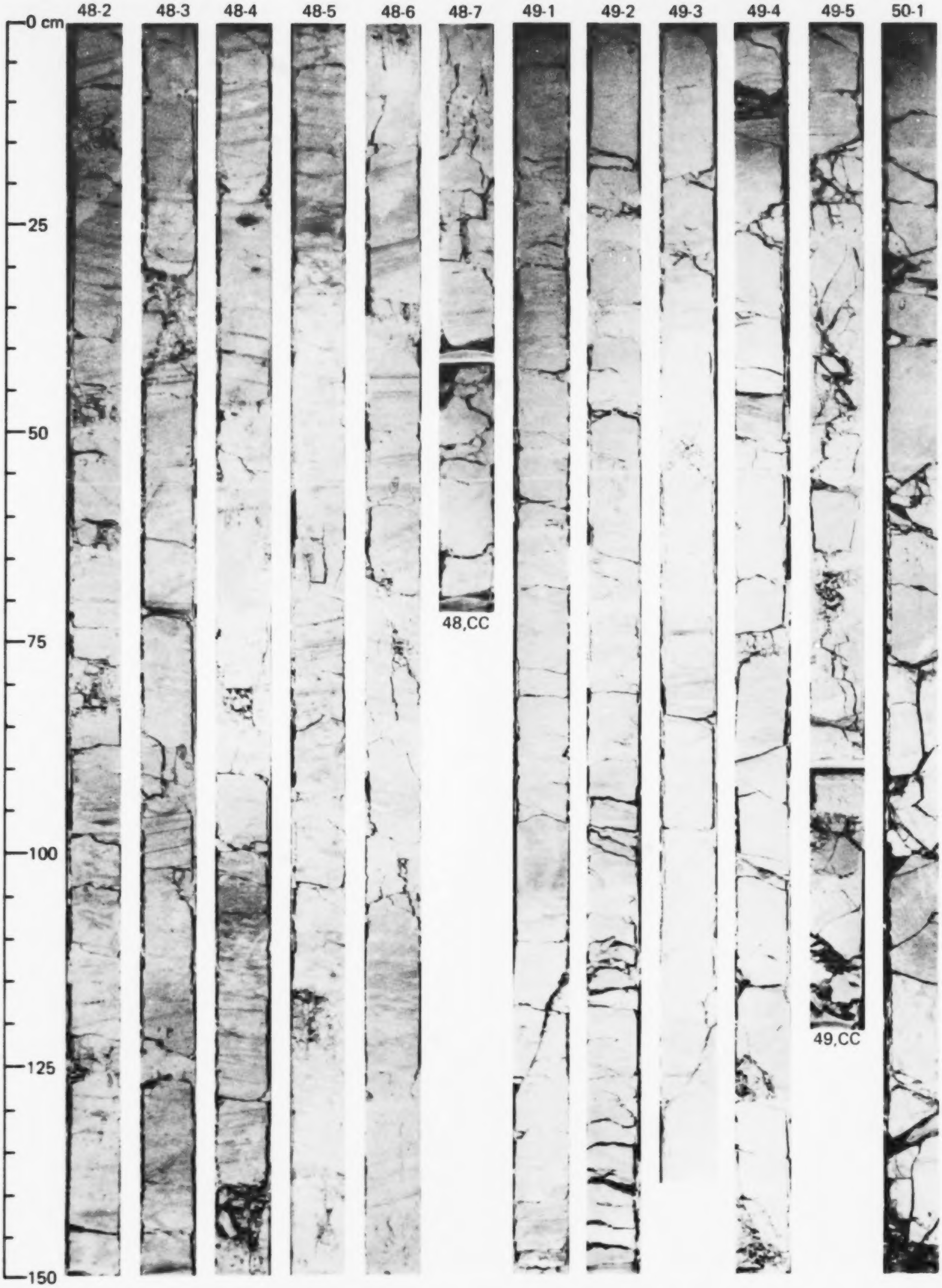
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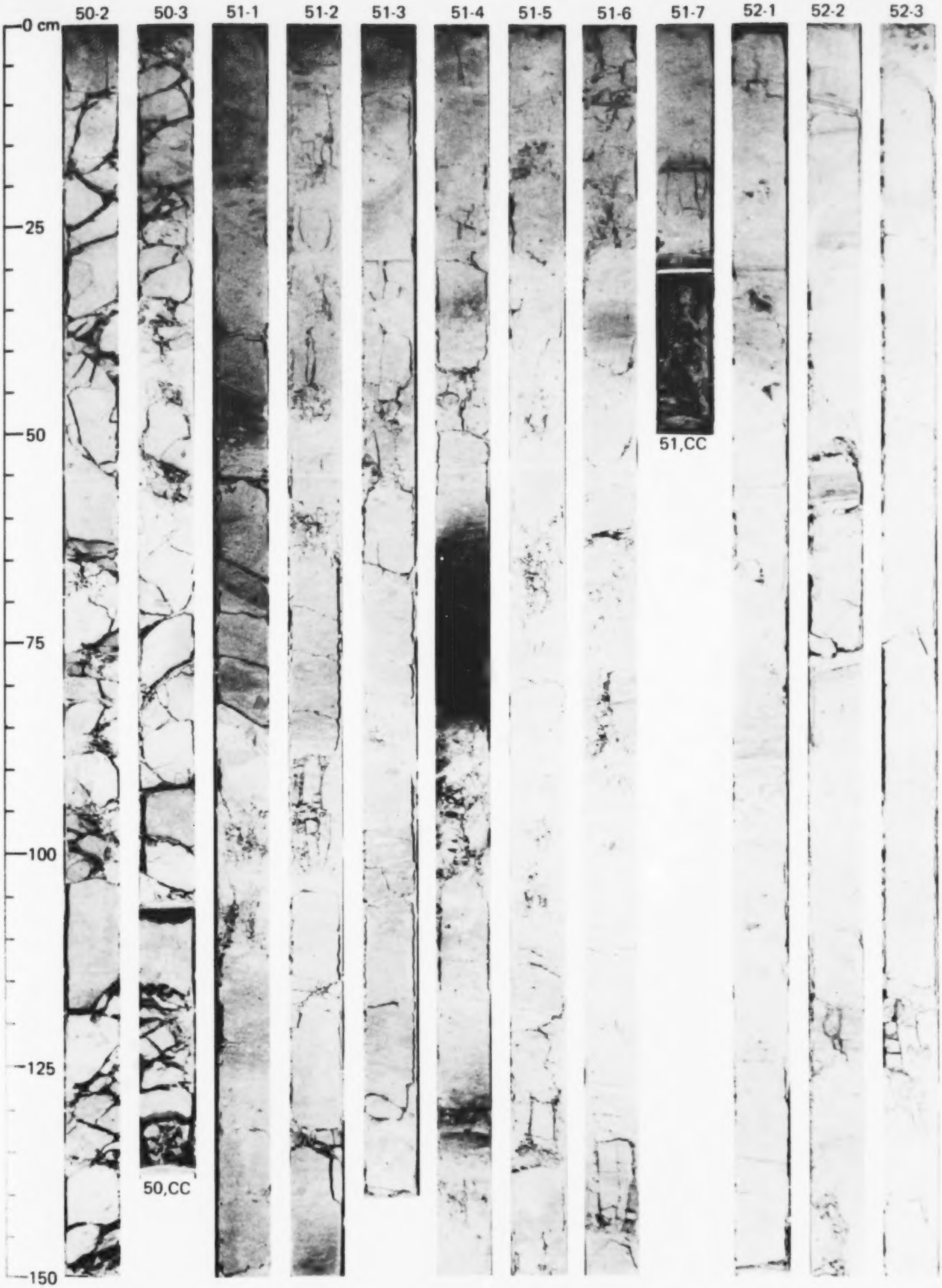
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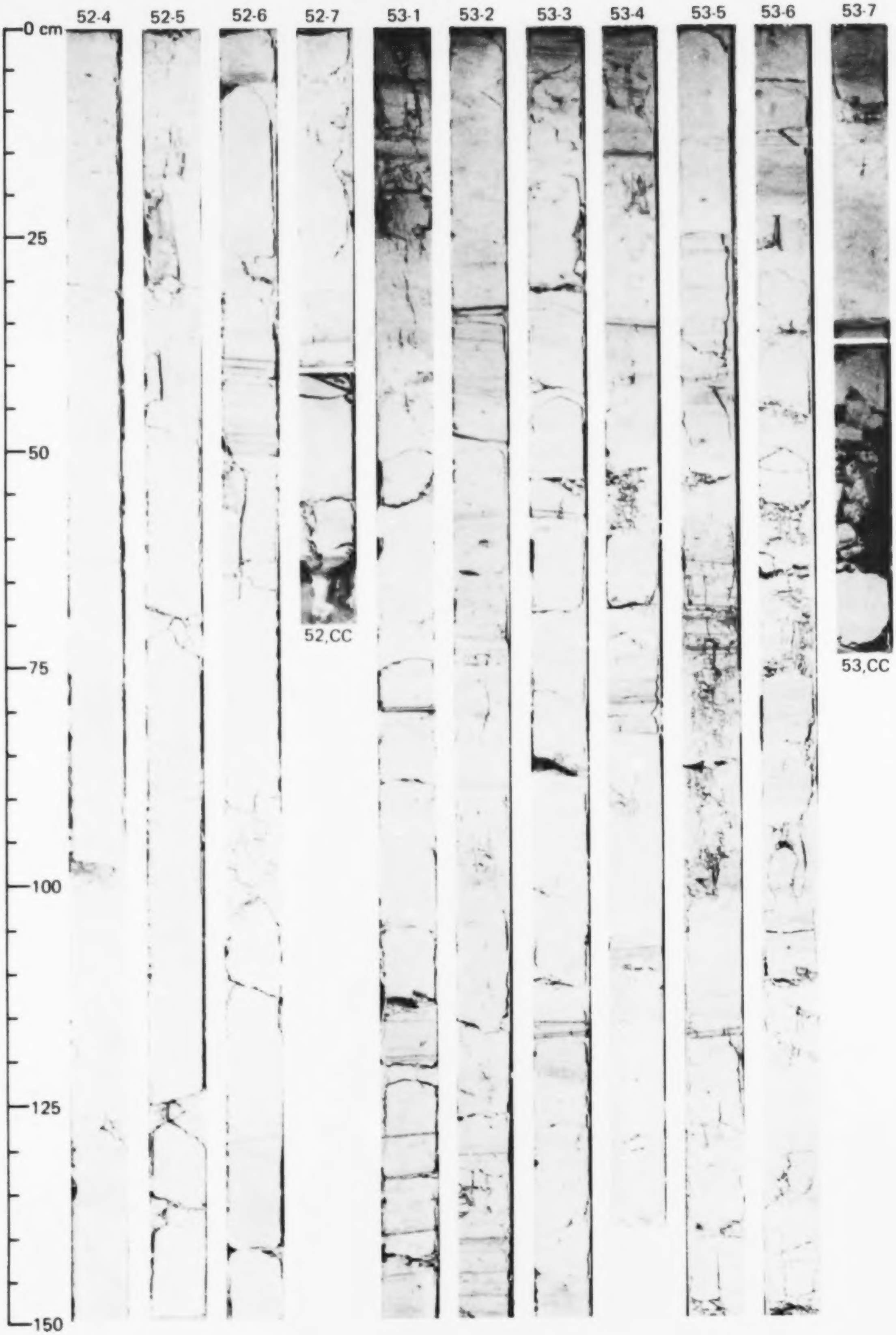
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7. SITE 591: LORD HOWE RISE, 31°S[1]

Shipboard Scientific Party[2]

HOLE 591

Date occupied: 19 December 1982

Date departed: 20 December 1982

Time on hole: 38 hr.

Position: 31°35.06′S; 164°26.92′E

Water depth (sea level; corrected m, echo-sounding): 2131

Water depth (rig floor; corrected m, echo-sounding): 2141

Bottom felt (m, drill pipe): 2142.2

Penetration (m): 283.1

Number of cores: 31

Total length of cored section (m): 283.1

Total core recovered (m): 278.21

Core recovery (%): 98.3

Oldest sediment cored:
  Depth sub-bottom (m): 283.1
  Nature: Nannofossil ooze
  Age: Early late Miocene

Basement: Not reached

HOLE 591A

Date occupied: 20 December 1982

Date departed: 22 December 1982

Time on hole: 37 hr.

Position: 31°35.06′S; 164°26.92′E

Water depth (sea level; corrected m, echo-sounding): 2131

Water depth (rig floor; corrected m, echo-sounding): 2141

Bottom felt (m, drill pipe): 2142.9

Penetration (m): 284.6

Number of cores: 30

Total length of cored section (m): 284.6

Total core recovered (m): 233.15

Core recovery (%): 81.9

Oldest sediment cored:
  Depth sub-bottom (m): 284.6
  Nature: Nannofossil ooze
  Age: Early late Miocene
  Measured velocity (km/s): 1.656 km/s at 249 m
  Shear strength: 145 g/cm^2 at 248 m;
    greater than 250 g/cm^2 below

Basement: Not reached

HOLE 591B

Date occupied: 23 December 1982

Date departed: 24 December 1982

Time on hole: 31 hr.

Position: 31°35.06′S; 164°26.92′E

Water depth (sea level; corrected m, echo-sounding): 2131

Water depth (rig floor; corrected m, echo-sounding): 2141

Bottom felt (m, drill pipe): 2141.5

Penetration (m): 500.4

Number of cores: 24

Total length of cored section (m): 229.8

Total core recovered (m): 130.86

Core recovery (%): 56.9

Oldest sediment cored:
  Depth sub-bottom (m): 500.4
  Nature: Foraminifer-bearing nannofossil chalk
  Age: Latest early Miocene
  Measured velocity (km/s): 2.218 km/s at 495 m
  Shear strength: 222 g/cm^2 at 294 m; greater values below

Basement: Not reached

Principal results: Site 591 consists of three holes. Hole 591 was cored continuously with the hydraulic piston corer (HPC) from 0–283.1 m sub-bottom; Hole 591A was cored continuously with the HPC from 0–246.5 m and rotary cored with the extended core barrel (XCB) from 246.5–284.6 m; and Hole 591B was cored continuously using conventional rotary coring from 270.6–500.4 m sub-bottom. Cores recovered with the first HPC are relatively undisturbed; those using the second HPC are slightly more disturbed because of rough sea conditions. The cores recovered using conventional rotary coring exhibit mixed quality: quite disturbed in the upper part of the section, although recovery was high; moderate recovery in the middle part of the sequence; and good quality cores with moderate to low recovery rates in the lowest part of the sequence. The extended core barrel did not function successfully at this site.

The sequence is made up of one lithostratigraphic unit represented mostly by foraminifer-bearing nannofossil ooze or foraminifer-rich nannofossil ooze. Site 591 is a continuous sequence from the late early Miocene (17 m.y. ago) to the Quaternary. The HPC part of the sequence is from early late Miocene (11 m.y. ago) to the Quaternary. The biostratigraphy is complete with no apparent hiatuses. A paleomagnetic polarity stratigraphy has been identified down to the late Gilbert Chron (about 3.5 m.y. ago).

---

[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

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The sequence is divided into three subunits based on changes in color and the relative abundance of foraminifers and calcareous nannofossils, and on the degree of lithification. The sedimentary sequence is similar to that at Site 590, but there are even more spectacular sedimentation rates within the early Pliocene: 131 m/m.y. These high rates are due to the high productivity of calcareous biogenic material occurring in the late Neogene at three sites in this area (590, 591, and 206). It is possible that the particularly high biogenic productivity in this area is related to the poorly known Subtropical Divergence that crosses the Tasman Sea at the latitude of these sites. Rates are much lower at the sites drilled to the north of Lord Howe Rise (Site 588) and to the south (Site 592). We have dismissed the possibility that the high sedimentation rates in the Pliocene are due to secondary reworking of material from elsewhere. This is because of the isolated location of Site 591, near the crest of a spur of Lord Howe Rise, and because clearly reworked material is absent from the section.

Diagenetic alteration of the microfossil sequence took place in younger sediments than at Site 590, because Site 591 has higher sedimentation rates. Foraminiferal recrystallization is already well advanced in the lower middle Miocene sediments, and calcareous nannofossils exhibit signs of overgrowths in lower Pliocene sediments. The higher rates of sedimentation at Site 591 have allowed finer stratigraphic resolution than at Site 590. A number of evolutionary sequences within the planktonic foraminifers are clearly exhibited in this expanded sequence.

Site 591 provides excellent opportunities for high-resolution microfossil and stable isotopic work in the upper Miocene through Quaternary section, which is well preserved. Radiolarians, diatoms, and silicoflagellates are persistently but rarely present throughout the entire section.

Benthic foraminifers are well represented in the late Miocene to Quaternary. Site 591 is intermediate in vertical depth profile (2131 m) between Sites 590 and 206. Benthic faunas typical of upwelling zones appear in the middle Miocene. Important faunal differences exist between Sites 591 and 590, reflecting different paleoceanographic histories at these different water depths. The paleoceanographic changes include both upward and downward migrations of some forms of benthic foraminifers.

Site 591 exhibits a valuable tephrochronology, based on many volcanic ash layers and inferred altered ash layers. There is an important Quaternary peak in activity, low activity in the Pliocene and late Miocene, high activity in the early late Miocene to late early Miocene. The mid-Neogene peak may extend through the middle Miocene, but core recovery was poor in this interval.

BACKGROUND AND OBJECTIVES

Site 591 lies near the crest of a southern spur of the eastern part of the Lord Howe Rise (Fig. 1). The spur extends outward into the New Caledonia Basin and is surrounded by turbidite fill to the east and south. The western edge of the spur is, in its northern part, separated from the main part of the Lord Howe Rise by a valley that slopes southward, leading toward a ponded turbidite sequence which slopes toward the level of the New Caledonia Basin. Thus the crest of the spur on which Site 591 is located is isolated from any influences of sediment transportation from the main part of the Lord Howe Rise. The seismic profile (Fig. 2) exhibits a relatively simple transparent layer about 520 m thick above a distinct reflector which is considered to represent the regional unconformity associated with the Eocene/Oligocene boundary.

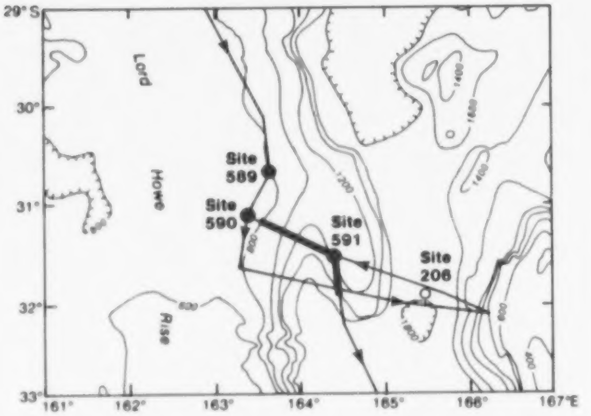


Figure 1. Regional bathymetry (fathoms) around Site 591, after Mammerickx et al. (1974). *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

Site 591 was selected to provide a Neogene–late Paleogene stratigraphic succession at water depths intermediate (about 2200 m) between Sites 590 (1299 m) and 206 (3196 m). A site at this intermediate depth is required to study changes in the vertical water mass structure of the southwest Pacific Ocean during the Neogene. These three sites, in combination, will provide an opportunity to carry out detailed studies of changes in the intermediate water masses between 1000 and 3000 m water depth. Site 591 is located midway between Sites 590 and 206, providing a compact suite of sites.

Determining the vertical temperature gradient of past oceans represents a problem that has not been studied in detail. Keigwin et al. (1979) examined the thermal structure of the Pacific Ocean for the early Pliocene, using sediment cores from water depths between 1000 and 4500 m and oxygen isotopic analyses of benthic foraminifers. This study demonstrated an approximate 1‰ difference in $\delta^{18}O$ between cores taken at 1000 m and those from 3000 m, representing a 3°C vertical temperature difference through the intermediate water masses. A major goal of Site 591, as with the other sites in the depth traverse, was to provide a continuous sequence of high stratigraphic resolution through the Neogene, which would allow us to compare and contrast the $\delta^{18}O$ and temperature gradients between selected intervals of time (see Kennett, this volume). For instance, we were interested in determining whether any changes occurred in the character of the vertical temperature gradient during the middle Miocene paleoceanographic event, when considerable ice accumulated on east Antarctica (Shackleton and Kennett, 1975; Kennett, 1978; Woodruff et al., 1981); during the terminal Miocene event, when a distinct shift in $\delta^{13}C$ occurred in the deep-sea sediment record 6.2 m.y. ago (Loutit and Kennett, 1979; Vincent et al., 1980; Haq et al., 1980), perhaps related to a major change in oceanic turnover rates (Bender and Keigwin, 1979); and during the late Pliocene, about 3 m.y. ago, when Northern Hemisphere ice sheets began to form (Shackleton and Opdyke, 1977).

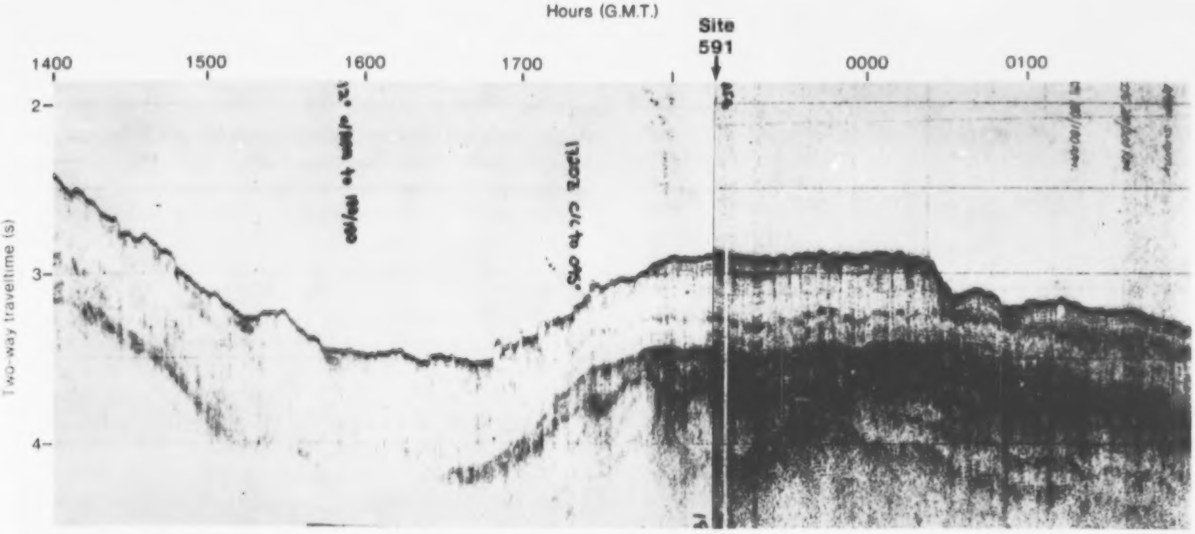


Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 591; bandpass filter 50–160 Hz.

Changes in $\delta^{13}C$ were also to be examined through the Neogene at the different water depths offered by the sites in this traverse. It has been determined that differences in $\delta^{13}C$ values represent valuable fingerprints of bottom waters.

The vertical depth traverse also was intended to provide a valuable opportunity to examine changes in benthic foraminiferal assemblages within the intermediate water masses during the Neogene. Benthic foraminifers are particularly valuable tracers of change in bottom-water characteristics through time (Douglas and Woodruff, 1981). They either migrate, evolve, or become extinct in response to bottom-water changes. The cores in the southwest Pacific depth traverse were expected to allow foraminiferal changes to be evaluated within a framework of paleodepths. This, in turn, should provide valuable data on the evolution of the intermediate water mass and allow comparisons with the stable isotopic data.

Site 591 is located at 2130 m, above the foraminiferal lysocline, and calcareous microfossil preservation was expected to be of high quality. Like Site 590, this site is located in waters transitional between the warm subtropical and temperate water masses and is of potential importance in correlating stratigraphic sequences of these areas. Because Site 590 was marked by very high sedimentation rates in the middle Miocene and younger sequences, high overburden pressure created much recrystallization of the microfossils in the middle and early Miocene. This has a potentially detrimental effect upon stable isotopic values. It was hoped that the calcareous microfossils through the early Neogene sequence at Site 591 would be less recrystallized and thus more useful for analyses of stable isotopes.

The final location of SW-6 (Site 591) changed during Leg 90. Originally SW-6 was to be located at a similar depth about 1° of latitude further north on the slope of the Lord Howe Rise. The original position was located on an Australian Bureau of Mineral Resources seismic profile which is of poor resolution but was the best available in the region. During the breakdown of the shipboard positioning computer, a useful survey conducted near Site 206 with the excellent water gun profiling system of the *Glomar Challenger* provided high-resolution data of the upper part of the sediment column. It was discovered that areas between about 1900 m and 2900 m on the slope of the rise exhibit heavily slumped topography. This seems also to be the case in the original area proposed for Site SW-6 drilling. A new area favorable for SW-6 objectives was discovered on the spur of the Lord Howe Rise, in unslumped terrain, exhibiting apparently uncomplicated stratigraphy and with a sediment thickness of 520 m down to the inferred regional unconformity separating the Eocene and Oligocene.

The drilling plans at Site 591 were to take two hydraulic piston cores and to rotary core (XCB) continuously through the Neogene sequence to the upper Oligocene sequence.

OPERATIONS

Site 591 (new SW-6): Downslope of Central Lord Howe Rise

The ship was positioned over the beacon with some difficulty because wind, current, and swell were all present from different directions. A combination variable length (VL) HPC–XCB bottom-hole assembly (BHA) was made up and run to the seafloor. Hole 591 was spudded at 1150 hr., 19 December, with a mud line core which verified the water depth as 2142 m (Table 1).

Piston coring proceeded using the 9.5-m VLHPC with only two shear pins. A nearly perfect series of cores was taken to a total depth of 283.1 m BSF in gradually stiffening carbonate ooze. Favorable conditions of vessel motion, repeated full stroke of the piston corer, and excellent core quality made this an exceptionally well preserved cored sequence which was marked by greater than

Table 1. Coring Summary, Site 591.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 591							
1	19	1215	2142.2-2145.6	0.0-3.4	3.4	3.38	99 +
2	19	1318	2145.6-2155.2	3.4-13.0	9.6	9.72	100 +
3	19	1410	2155.2-2164.8	13.0-22.6	9.6	9.52	99 +
4	19	1503	2164.8-2174.4	22.6-32.2	9.6	9.47	99 +
5	19	1605	2174.4-2184.0	32.2-41.8	9.6	8.82	92
6	19	1705	2184.0-2193.6	41.8-51.4	9.6	9.57	100
7	19	1805	2193.6-2203.2	51.4-61.0	9.6	9.12	93
8	19	1900	2203.2-2212.8	61.0-70.6	9.6	8.98	98
9	19	1950	2212.8-2222.4	70.6-80.2	9.6	9.44	100 +
10	19	2055	2222.4-2232.0	80.2-89.8	9.6	9.65	100 +
11	19	2150	2232.0-2241.6	89.8-99.4	9.6	9.16	95
12	19	2310	2241.6-2251.2	99.4-109.0	9.6	9.56	99.5
13	19	2350	2251.2-2260.5	109.0-118.3	9.3	9.19	98.8
14	20	0050	2260.5-2269.8	118.3-127.6	9.3	9.67	100 +
15	20	0200	2269.8-2279.1	127.6-136.9	9.3	9.64	100 +
16	20	0300	2279.1-2288.4	136.9-146.2	9.3	9.63	100 +
17	20	0400	2288.4-2297.7	146.2-155.5	9.3	9.71	100 +
18	20	0450	2297.7-2307.0	155.5-164.8	9.3	9.29	100 +
19	20	0600	2307.0-2316.5	164.8-174.3	9.5	9.55	100 +
20	20	0700	2316.5-2326.0	174.3-183.8	9.5	9.59	100 +
21	20	0740	2326.0-2335.5	183.8-193.3	9.5	9.47	99.7
22	20	0843	2335.5-2344.9	193.3-202.7	9.4	8.55	90.9
23	20	0940	2344.9-2354.3	202.7-212.1	9.4	9.50	100 +
24	20	1035	2354.3-2363.7	212.1-221.5	9.4	8.63	91.8
25	20	1145	2363.7-2373.3	221.5-231.1	9.6	9.73	100 +
26	20	1245	2373.3-2382.9	231.1-240.7	9.6	8.76	91
27	20	1345	2382.9-2392.5	240.7-250.3	9.6	9.71	100 +
28	20	1445	2392.5-2402.0	250.3-259.8	9.5	9.11	95
29	20	1615	2402.0-2411.5	259.8-269.3	9.5	8.93	94
30	20	1730	2411.5-2416.5	269.3-274.3	5.0	4.40	88
31	20	1900	2416.5-2425.3	274.3-283.1	8.8	8.76	99
					283.10	278.21	98.3
Hole 591A							
1	20	2052	2140.9-2150.1	0.0-9.2	9.2	9.16	100
2	20	2150	2150.1-2159.7	9.2-18.8	9.6	8.73	90.9
3	20	2300	2159.7-2169.3	18.8-28.4	9.6	6.40	66.6
4	20	2340	2169.3-2178.9	28.4-38.0	9.6	8.30	86.4
5	21	0055	2178.9-2188.5	38.0-47.6	9.6	8.67	90.3
6	21	0200	2188.5-2198.1	47.6-57.2	9.6	8.44	87.9
7	21	0245	2198.1-2207.7	57.2-66.8	9.6	9.28	96.6
8	21	0350	2207.7-2217.3	66.8-76.4	9.6	7.92	82.5
9	21	0445	2217.3-2226.9	76.4-86.0	9.6	7.34	76.4
10	21	0540	2226.9-2236.5	86.0-95.6	9.6	6.92	72.0
11	21	0645	2236.5-2246.1	95.6-105.2	9.6	7.95	82.8
12	21	0745	2246.1-2255.4	105.2-114.5	9.3	8.61	92.5
13	21	0840	2255.4-2264.7	114.5-123.8	9.3	8.55	91.9
14	21	0940	2264.7-2274.0	123.8-133.1	9.3	9.20	95.8
15	21	1040	2274.0-2283.3	133.1-142.4	9.3	9.39	100 +
16	21	1140	2283.3-2292.6	142.4-151.7	9.3	8.77	94
17	21	1240	2292.6-2301.9	151.7-161.0	9.3	9.24	99
18	21	1340	2301.9-2311.4	161.0-170.5	9.5	8.86	93
19	21	1440	2311.4-2320.9	170.5-180.0	9.5	8.79	92
20	21	1540	2320.9-2330.4	180.0-189.5	9.5	8.27	87
21	21	1040	2330.4-2339.8	189.5-198.9	9.4	9.31	99
22	21	1745	2339.8-2349.2	198.9-208.3	9.4	9.48	100 +
23	21	1900	2349.2-2358.6	208.3-217.7	9.4	9.25	98
24	21	2030	2358.6-2368.2	217.7-227.3	9.6	8.29	86
25	21	2130	2368.2-2377.8	227.3-236.9	9.6	8.18	85
26	21	2235	2377.8-2387.4	236.9-246.5	9.6	8.41	87.6
27	22	0100	3387.4-2396.9	246.5-256.0	9.5	7.31	76.9
28	22	0445	2396.9-2406.4	256.0-265.5	9.5	0.0	0.0
29	22	0545	2406.4-2415.9	265.5-275.0	9.5	0.0	0.0
30	22	0645	2415.9-2425.5	275.0-284.6	9.6	4.13	43
					284.6	233.15	81.9
Hole 591B							
1	23	0600	2411.5-2421.1	270.6-280.2	9.6	3.69	38.4
2	23	0645	2421.1-2430.7	280.2-289.8	9.6	9.48	98.7
3	23	0730	2430.7-2440.3	289.8-299.4	9.6	7.42	77.2
4	23	0820	2440.3-2449.7	299.4-308.8	9.4	7.08	73.7
5	23	0905	2449.7-2459.1	308.8-318.2	9.4	5.00	52.0
6	23	1000	2459.1-2468.5	318.2-327.6	9.4	7.86	81.8
7	23	1045	2468.5-2478.1	327.6-337.2	9.6	9.00	93.7
8	23	1130	2478.1-2487.7	337.2-346.8	9.6	2.17	22.6
9	23	1235	2487.7-2497.3	346.8-356.4	9.6	2.69	28.0
10	23	1335	2497.3-2506.9	356.4-366.0	9.6	4.31	44.9
11	23	1435	2506.9-2516.5	366.0-375.6	9.6	1.63	17.0
12	23	1535	2516.5-2526.1	375.6-385.2	9.6	2.51	26.1
13	23	1620	2526.1-2535.7	385.2-394.8	9.6	3.24	33.7
14	23	1740	2535.7-2545.3	394.8-404.4	9.6	2.21	23.0
15	23	1840	2545.3-2554.9	404.4-414.0	9.6	4.11	42.8
16	23	1935	2554.9-2564.5	414.0-423.6	9.6	0.49	5.1
17	23	2040	2564.5-2574.1	423.6-433.2	9.6	5.06	52.7
18	23	2140	2574.1-2583.7	433.2-442.8	9.6	8.70	90.6
19	23	2240	2583.7-2593.3	442.8-452.4	9.6	7.86	81.9
20	23	2340	2593.3-2602.9	452.4-462.0	9.6	7.74	80.6
21	24	0045	2602.9-2612.5	462.0-471.6	9.6	4.68	48.7
22	24	0145	2612.5-2622.1	471.6-481.2	9.6	7.98	83.1
23	24	0245	2622.1-2631.7	481.2-490.8	9.6	9.71	100 +
24	24	0345	2631.7-2641.3	490.8-500.4	9.6	6.24	65.0
					229.80	130.86	56.9

98% recovery. The hole was terminated despite continued full stroke when excessive pullout loads endangered the coring tool.

Hole 591A

The bit was pulled to the mud line and the vessel was offset 100 ft. in preparation for a repeat piston core sequence. The new hole was spudded at 2012 hr., 20 December. Cores were staggered to overlap those from Hole 591. Rougher weather resulted in poorer core quality and recovery in the repeat piston core sequence. Again full stroke was achieved on all cores.

Piston coring was stopped at 246.5 m BSF to avoid excess overpull. The XCB was then deployed a total of six times. Each of the six attempts resulted in a severely shattered liner which created much difficulty in removing the liners and/or cores from the core barrels.

Additional problems were encountered when several of the XCB core barrels did not land at their proper latch-in point above the bit. Each seemed to become stuck at a position 70–80 m above its normal landing point and required repeated jarring by the wireline to become free. No immediate cause for or solution to this phenomenon could be found.

Both these problems led to the termination of Hole 591A, and the pipe was tripped to allow us to change over to the standard rotary system and inspect the BHA. Subsequent inspection of all BHA components including disassembly and servicing of the bumper subs failed, however, to reveal why the barrels had become stuck.

During the pipe trip the vessel was subjected to a severe combination of wind, swell, and current. In an attempt to hold the roll to a minimum for safety of personnel on the rig floor while pulling out of the hole, the vessel was allowed to wander about 3 mi. from the beacon. When we returned to the beacon the adverse conditions made positioning exceedingly difficult unless the ship's heading was such that the rolls made running in the hole unsafe. After the ship spend 7 hr. seeking optimum positioning while waiting on the weather, the wind abated enough to allow the vessel to position in automatic with a safe level of vessel motion.

Hole 591B

A short-hook-up BHA, spaced out for standard rotary drilling, was run back to the seafloor and the bit was washed to 270.6 m BSF to begin rotary coring. After the wash barrel was retrieved, 24 rotary cores were taken to a depth of 500.4 m BSF (Table 1). At this point fossils were too badly preserved to be valuable for analyses so the hole was terminated.

Core quality was mediocre and recovery was below average, largely because of unfavorable sea conditions and vessel motion. The pipe was tripped, the rig secured for sea, and the ship was underway for second-priority Site SW-3 at 0950 hr., 24 December 1982.

LITHOSTRATIGRAPHY

The sedimentary sequence recovered at Site 591 is a calcareous biogenic facies that constitutes a single lithostratigraphic unit. The basic color of the sediment is light gray, with greenish gray interbeds. The main biogenic components are calcareous nannofossils and foraminifers (Fig. 3). Biosiliceous components are occasionally present in trace amounts, and increase slightly in abundance below Core 591-27 and throughout Hole 591B. Siliceous components consist mainly of fragments of radiolarians, diatoms, and sponge spicules, and silicoflagellates appear in Cores 591-21 and 591A-23.

Nonbiogenic components comprise a very small proportion of the sediment. Quartz, feldspars, mica, possible heavy minerals, and micritic carbonate are generally present. Micritic carbonate significantly increases below Core 591B-18. Trace quantities of clear volcanic glass occur throughout the sequence. Ash layers are present n Cores 591-2, 591-5, 591-10 and possibly 591-13, and n 591A-1 and possibly 591A-2 (Fig. 4). Pockets of volcanic glass also occur in Core 591A-25. Zeolites are present in trace amounts in Cores 591-2 and 591-4. Palagonite is also present in Cores 591-31 and 591A-3. Light greenish gray laminae are common and often associated with underlying gray laminae of iron sulfides. These laminae (Fig. 4) may represent alteration products of devitrified volcanic glass. These paired color bands occur more frequently above 80 m BSF (Cores 591-1 to 591-9 and 591A-1 to 591A-8), as well as in Hole 591B below Core 591B-3 (Fig. 4). Authigenic iron sulfides occur within burrows and foraminifer tests, and as finely dispersed gray pockets, halos, and laminae throughout the sequence. Pyrite nodules are present in Hole 591B.

The sequence at Site 591 is divided into three subunits based on color, on the relative abundance of foraminifers and calcareous nannofossils, and on the degree of lithification (Fig. 5).

Subunit IA extends from the seafloor to 0.62 m sub-bottom in Hole 591 and to 0.50 m in Hole 591A. This subunit is late Quaternary in age. The sediment is yellowish gray to pale yellowish brown and consists of a foraminifer-bearing nannofossil ooze. Subunit IA corresponds to the zone of oxidation.

Subunit IB extends from the base of the oxidized layer to 289.8 m sub-bottom (Quaternary to upper Miocene). The sediments, light gray in color, range from a foraminifer-bearing nannofossil ooze to a nannofossil ooze. Greenish gray levels are frequent in this subunit and contain slightly more foraminifers (5 to 10%) than ight gray oozes.

Subunit IC extends from 289.8 m sub-bottom to the ottom of Hole 591B (500.4 m sub-bottom). This subnit is late Miocene to early Miocene in age. The sediments, very light gray to light greenish gray, range from foraminifer-bearing nannofossil chalk to a nannofossil halk.

Bioturbation in Hole 591 is important in Cores 591-7 nd 591-8, and Cores 591-9 to 591-31 are slightly to moderately bioturbated. The entire sequence in Hole 591A is ightly to moderately bioturbated, with the exception f Core 591A-13, which is extremely bioturbated. Sediments in Hole 591B are moderately bioturbated in Cores 91B-4 and 591B-5, as well as in 591B-15 to 591B-24. lany burrows—gray, light greenish gray, and grayish ellow green—are present. Examples of Planolites-like urrows are apparent in the three holes. Zoophycos-like burrows are common below Core 591B-3. Flaser-type structures appear below Core 591B-16. Microfractures are present in Cores 591B-5 to 591B-7 and in 591B-12.

The sediment becomes more indurated with depth. Sediment above 290 m sub-bottom is an ooze and becomes progressively stiffer with depth, especially below 155 m (soft to stiff). Sediment below 290 m (Core 591B-3) is chalk, with clear recrystallization below 300 m (Core 591B-4). Sediment becomes very hard and recrystallization is widespread below 443 m (591B-19).

The first section of Cores 591-1 to 591-12 is generally soupy or very disturbed. Sections 1 to 3 of Cores 591-12 to 591-24 are slightly to very disturbed. Cores 591-24 to 591-31 are undisturbed. All cores in Hole 591A are soupy or disturbed in the first section. Cores 591A-5 to 591A-9 are moderately to very disturbed in Sections 1 to 4, and Cores 591A-9 to 591A-13 and 591A-18 to 591A-30 are slightly to very disturbed in Sections 1 and 2. Cores 591B-1, 591B-2 and 591B-8 to 591B-13 are very disturbed and consist of biscuits of sediment surrounded by a slurry of soft ooze introduced during the coring process.

PHYSICAL PROPERTIES

Combining Holes 591A and 591B yields a continuously cored section with good recovery, nearly 500 m long, from which numerous physical properties were obtained. Gravimetric, sonic velocity, and shear strength measurements were systematically performed at small intervals along the HPC cores and most sections were run through the continuous GRAPE scanning apparatus (see Introduction for specific techniques). Grain densities were determined by standard gravimetric analyses and the results are shown in Figure 6A. Below a depth of 300 m, the data were obtained from solid chunk samples rather than from sediment-filled cylinders (Boyce, 1976). The grain densities are quite uniform at this level and are consistent with calcareous sediments ($CaCO_3$ grain density = 2.71 g/cm^3). The carbonate content of these sediments is quite high (Fig. 6B). At shallower depths, however, the grain density varies erratically. It appears that the chunk method used with lithified samples is more accurate and reliable than the cylinder technique which is employed for soft, easily deformable sediments.

The GRAPE porosity data are plotted versus depth in Figure 7A, where the GRAPE wet-bulk densities have been converted to porosities by assuming an average grain density of 2.691 g/cm^3. The results are averaged across each meter of depth, and these mean values are depicted by a solid line. The porosity profile of Hole 591 coincides well with that of the adjacent Holes 591A and 591B (Fig. 7B).

All of the acoustic velocity and shear strength measurements were made on split cores, parallel to bedding. The P-wave velocity results are plotted versus depth in Figure 7C. This information, when combined with the GRAPE porosity profile, yields a relationship between compressional velocity and porosity (Fig. 7D). A sharp increase in this property is observed as the sediment porosity approaches 53%.

Similarly, shear strength is plotted versus depth in Figure 7E, where a sudden rise in its magnitude is seen to occur at approximately 250 m. At a depth of 290 m, lith-

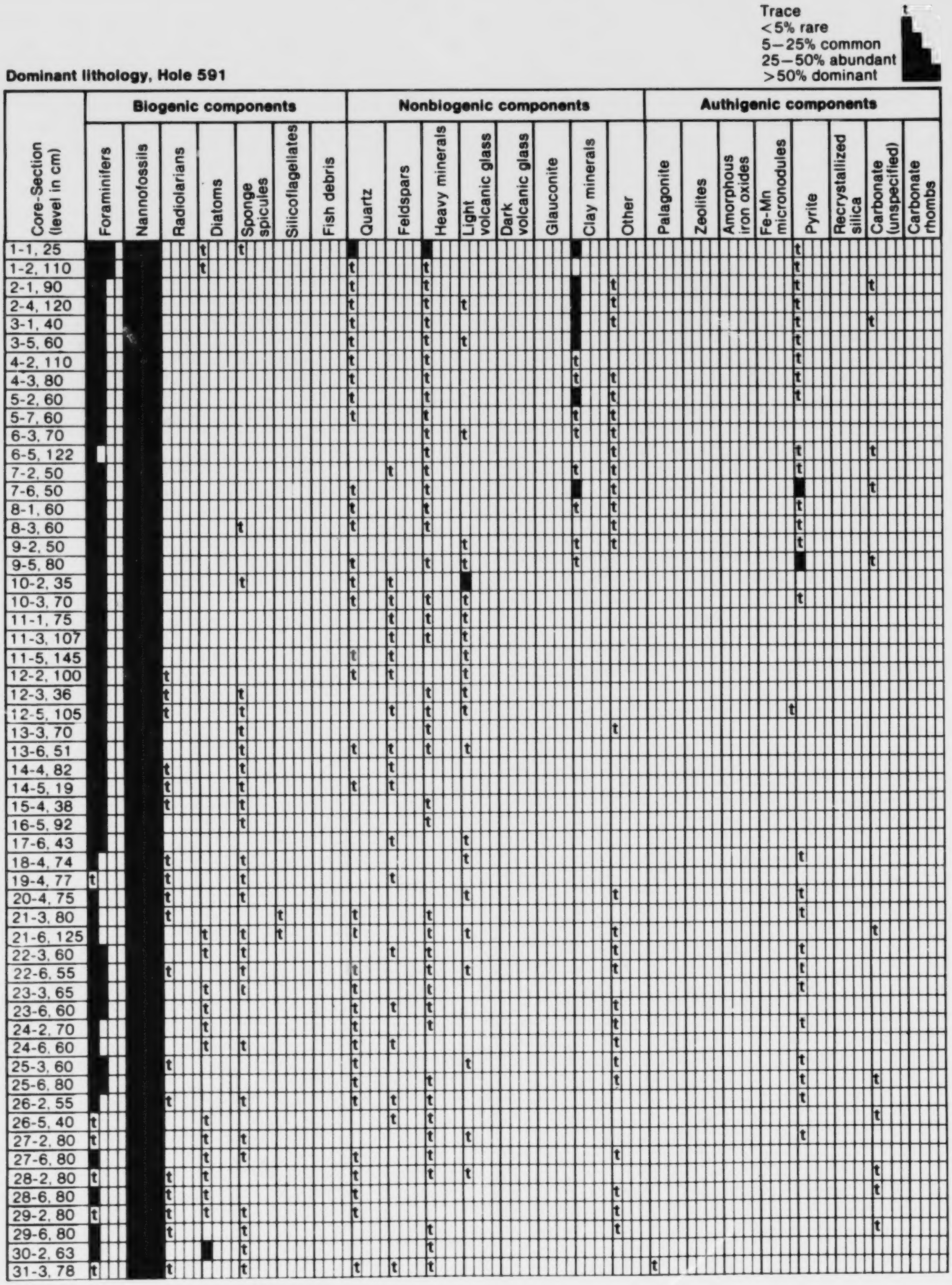


Figure 3. Smear slide summary, Site 591.

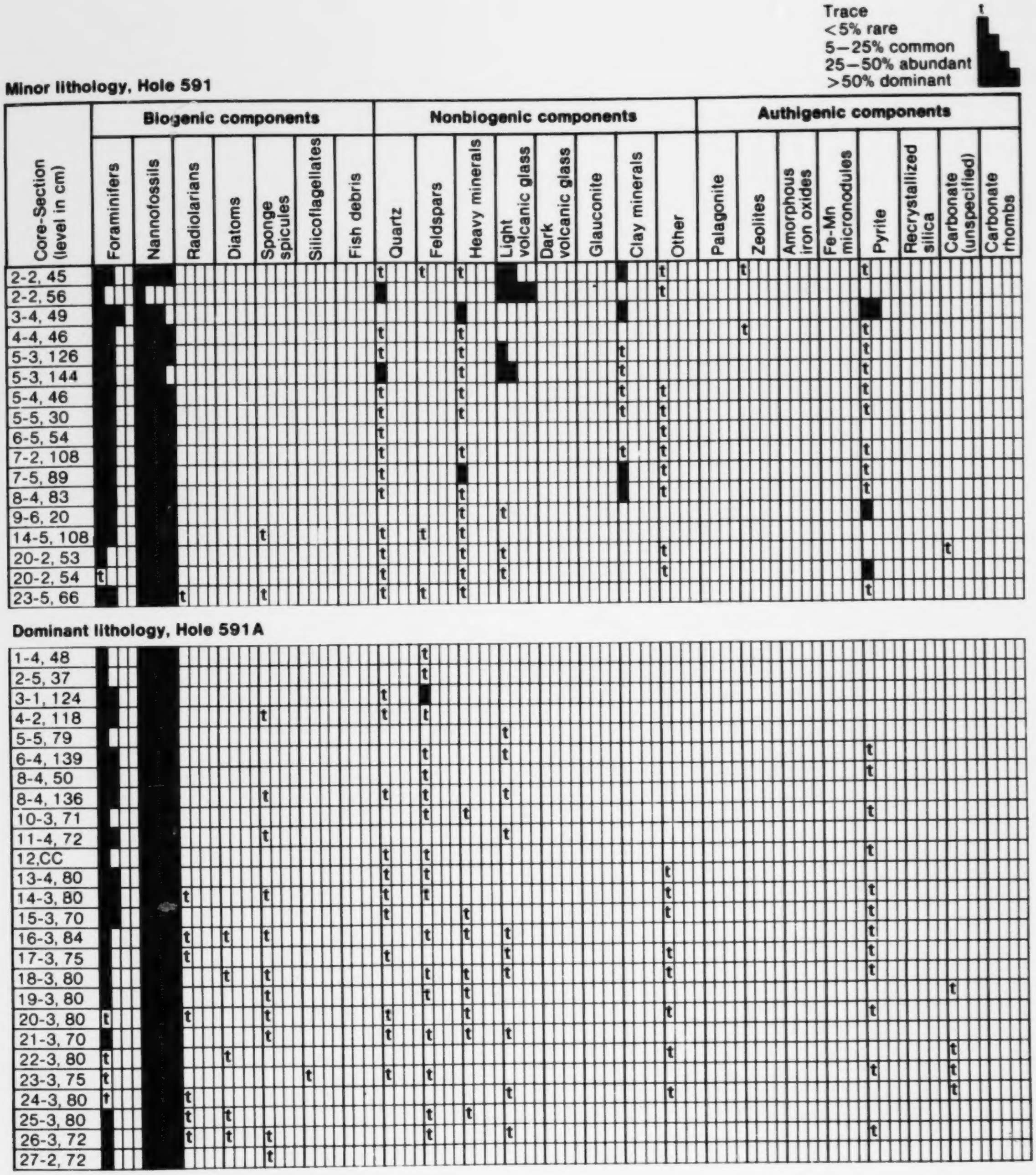


Figure 3. (Continued).

ification prevents further testing as the shear strength progresses beyond the range of the Wykeham-Farrance vane device. These data depict the same behavior as that described by the acoustic velocity results of Figure 7D. The shear strength increases dramatically as a declining porosity approaches 53% (Fig. 7F).

A relationship between acoustic impedance and depth can be established by combining the compressional velocity results with the GRAPE wet-bulk density profile (Fig. 7G). A more detailed presentation and analysis of the physical properties results for Site 591 is reported by Morin (this volume).

SEISMIC STRATIGRAPHY

Figure 8 illustrates a portion of the shipboard water gun seismic profile collected during the approach to Site 591. Five acoustic units have been identified (A–E), equivalent to the regional acoustic units of Willcox et al.,

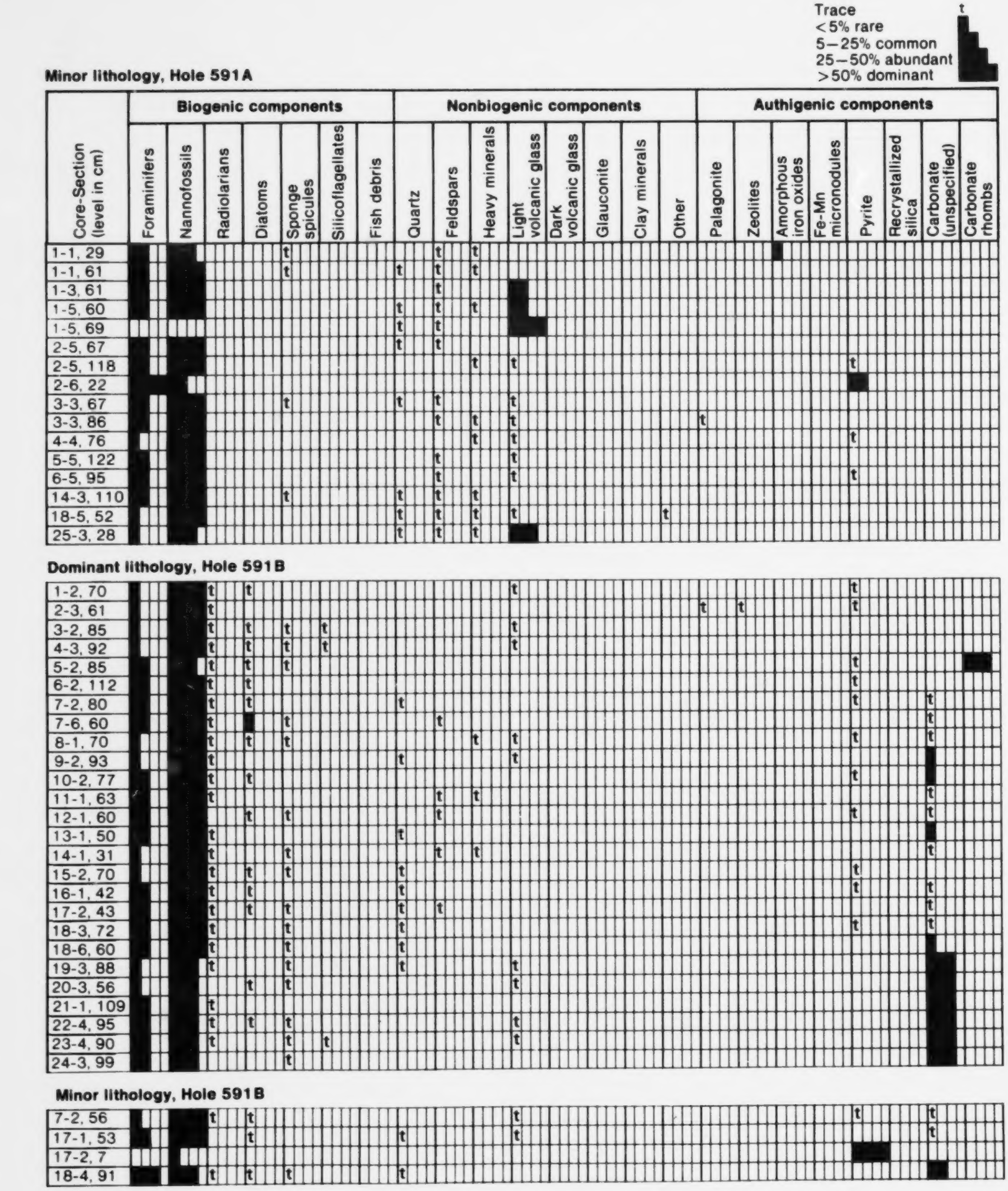


Figure 3. (Continued).

1980. These are correlated in part with the lithology of the site (lithostratigraphic Subunits IA, IB, and IC).

The five acoustic units are identical to those described in the Seismic Stratigraphy section for Site 590, with the exception that Unit E at Site 591 may represent acoustic basement, and not the graben-filling low-amplitude unit described earlier. Some obvious erosion has occurred immediately to the northwest of the site, with uppermost reflectors below the reflected wave form showing evidence of truncation. However the actual site locality, at a slightly shallower water depth, appears to overlie a relatively complete stratigraphic sequence.

Site 591 was drilled to a total depth of 500.4 m, through acoustic Unit A into acoustic Unit B. The sedimentary section comprises three lithostratigraphic subunits (IA, IB, and IC), ranging in age from Quaternary to latest early Miocene. Subunit IA is too thin to be shown on Figure 8. Lithologies range from foraminifer-bearing nannofossil ooze or nannofossil ooze to foraminifer-bearing nannofossil chalk, with the ooze/chalk boundary occurring at a sub-bottom depth of approximately 290 m.

The most significant observation from the data outlined above is the gradation from ooze to chalk, which occurs within the upper Miocene. This occurs approximately 40 m above the selected upper boundary of acoustic Unit B, assuming an interval velocity of 2000 m/s averaged from shipboard velocimeter measurements. The greater amplitudes observed near the top of acoustic Unit B are considered to be due at least in part to variations in the degree of induration of sediments observed within lithostratigraphic Unit IC.

BIOSTRATIGRAPHY

Site 591 was drilled with the objective of recovering a deep-water Neogene section that could be combined with those from Sites 590 (1299 m) and 206 (3196 m) to form a depth traverse through the three major bottom-water types in this area of the Tasman Sea. The planktonic biostratigraphies and faunas were expected to be very similar to those at Site 590, which is located only about 100 km to the west.

Three holes were cored at Site 591. Hole 591 contains 31 cores and includes sediments of Quaternary through late Miocene age. Hole 591A repeated the section at Hole 591. Hole 591B overlapped in part with the upper Miocene section at Hole 591, then recovered Miocene sediment down to the uppermost lower Miocene. The nannoplankton and planktonic foraminiferal zones are shown in Figure 9.

The planktonic foraminiferal faunas at Site 591 are well preserved through the Pliocene and upper Miocene; below that point preservation deteriorates rapidly and by the lower middle Miocene most forms are recrystallized. In the few lower Miocene cores, many species are barely recognizable because of recrystallization and cementation. The faunas are identical to those from nearby Site 590; however, three biostratigraphic zones not recognized at Site 590 were recovered at Site 591. These are the lower Pliocene *Globorotalia sphericomiozea* Zone, the *Orbulina suturalis* Zone, and the *Praeorbulina glomerosa curva* Zone of the early middle Miocene. The identification of these zones is attributed to the very high sedimentation rates at Site 591.

Calcareous nannoplankton were very abundant and were preserved throughout the section; however, their preservation was, in general, worse than at Site 590. Overgrowths occur in the Pliocene, and the Miocene discoasters are difficult to recognize. As with the foraminifers, preservation deteriorated rapidly toward the bottom of the hole. The biostratigraphy of the section was the same as at Site 590.

Benthic foraminiferal faunas are well preserved from the Quaternary through the upper Miocene, but below that faunas are impoverished; in the middle Miocene, recrystallization of the individuals increases and by the lower Miocene few if any forms could be recognized because of recrystallization and cementation. The benthic faunas contain many of the same species found at site 590; however, an indigenous element was recognized.

Radiolarians, diatoms, and silicoflagellates were found in most cores throughout the section; they were rare to common down to the lower middle Miocene.

Planktonic Foraminifers

Zones

The following zones were identified at Site 591; the zonal boundary markers are shown below:

Globorotalia truncatulinoides Zone
  L. A. *Globorotalia tosaensis*
Globorotalia truncatulinoides–G. tosaensis Zone
  I. A. *G. truncatulinoides*
Globorotalia tosaensis Zone
  I. A. *G. tosaensis*
Globorotalia inflata Zone
  I. A. *G. inflata*
Globorotalia crassaformis Zone
  I. A. *G. crassaformis*
Globorotalia puncticulata Zone
  I. A. *G. puncticulata*
Globorotalia sphericomiozea Zone
  L. A. *G. conomiozea*
Globorotalia conomiozea Zone
  I. A. *G. conomiozea*
Globigerina nepenthes Zone
  L. A. *Neogloboquadrina continuosa*
Neogloboquadrina continuosa Zone
  L. A. *Globorotalia mayeri*
Globorotalia mayeri Zone
  L. A. *G. peripheroacuta*
Globorotalia johsi s.l. Zone
  I. A. *G. peripheroacuta*
Orbulina suturalis Zone
  I. A. *O. suturalis*
Praeorbulina glomerosa curva Zone
  I. A. *P. glomerosa*
Globorotalia miozea Zone

Faunas

The preservation of the abundant planktonic foraminiferal faunas was good down to the early late Miocene *N. continuosa* Zone, but in this zone and sporadically down through the middle Miocene into the lower Miocene the preservation deteriorated; this poor preservation is especially true for the lowermost middle Miocene and down into the lower Miocene.

As expected, the species content of the zones was almost identical to those at Site 590.

Benthic Foraminifers

Benthic foraminifers were examined from all core catchers from Holes 591 and 591B. Benthic faunas are well preserved in the Quaternary, Pliocene, and upper

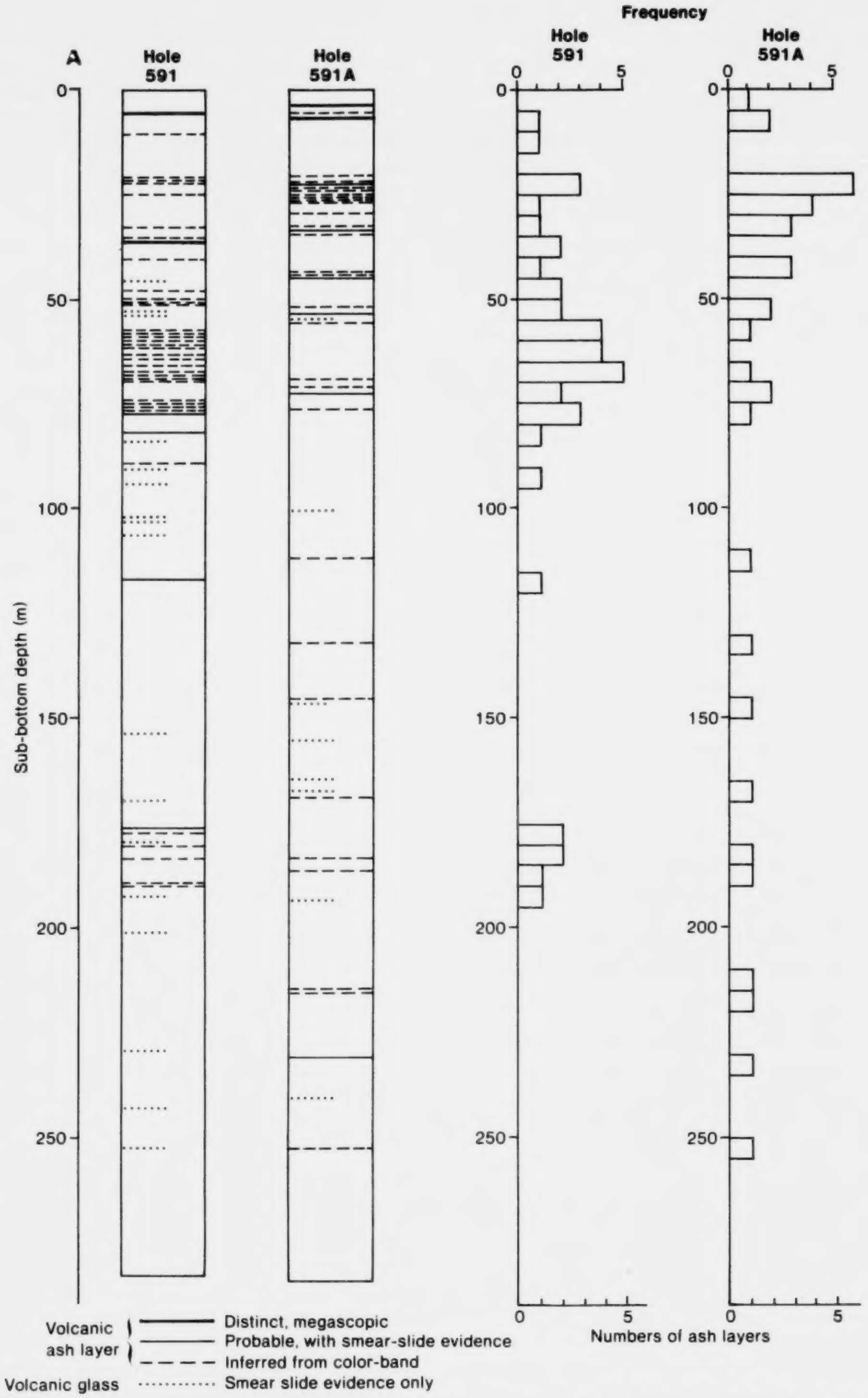


Figure 4. A. Horizons and histograms of distinct, megascopic volcanic ash layers (thick lines) and possibly devitrified ash layers (thin or broken lines) of Holes 591 and 591A are shown. Thickness of each layer is more than 1.0 cm and is typically several centimeters. Single, very thin laminae less than 1 mm thick are omitted. B. A compiled histogram showing the frequency of ash layers at Site 591, with careful correlation between Holes 591 and 591A. Because of relatively poor recovery in Hole 591B, a normalization is also shown as "ash-layer density" (m^{-1}), which is the averaged number of ash layers in every 10-m interval (Holes 591 and 591A) or in every core (Hole 591B).

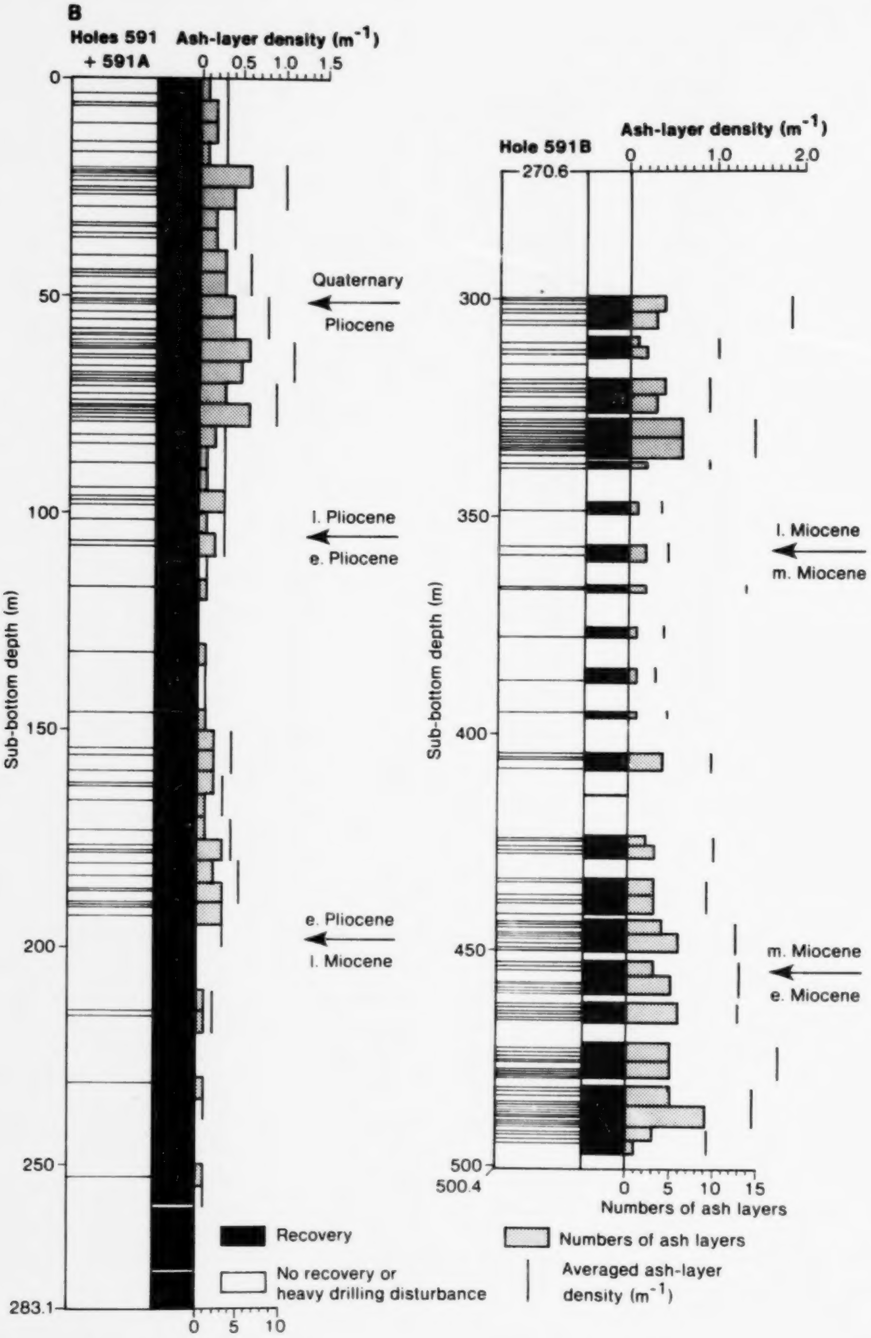


Figure 4. (Continued).

iocene sediments; however, faunas are impoverished, d the preservation of several taxa deteriorates below e upper Miocene. Recrystallization was first noticed the mid-middle Miocene; by the lower Miocene few if y individuals could be recognized because of the ce- entation of the carbonates.

Benthic faunas at Site 591 contain many of the same species found at the shallower Site 590, but did reveal an indigenous element consisting of several miliolid species, *Favocassidulina fava, Uvigerina pygmaea, Angulogerina angulosa*, and *Epistominella exigua*. The species that occurred very rarely at Site 591, including *Bolivinopsis*

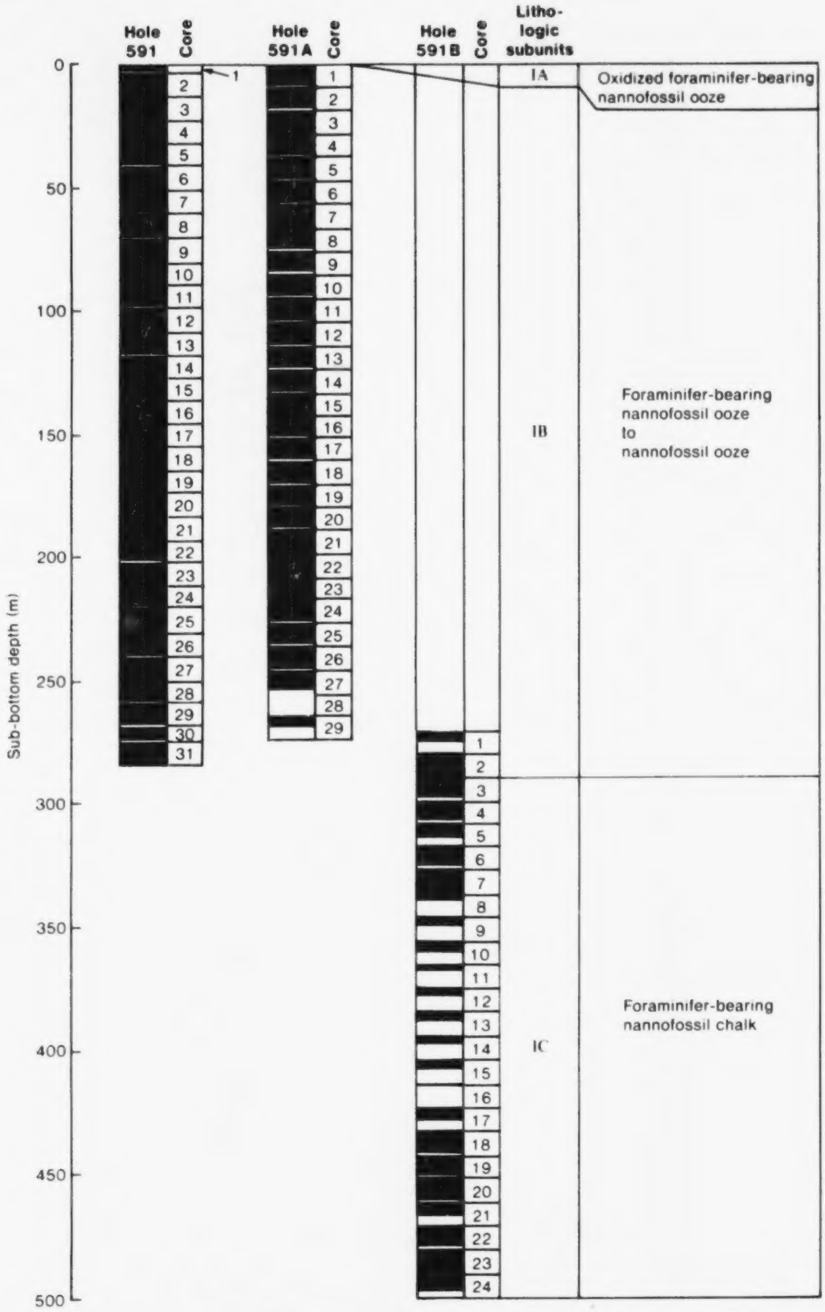


Figure 5. Lithostratigraphy of Site 591 (recovery in black).

praelonga, Pleurostomella alternans, Rectuvigerina multistriata, and *Cibicidoides rugosus*, to name only a few, were those which were common and typical of the shallower Site 590.

Because of the poor preservation, little could be derived from the lower to mid-middle Miocene faunas at Site 591 (591B-16 to 591B-24,CC). Species resistant to dissolution are the same as found at the other sites. *Cibicidoides tuxpamensis* does not range above the *Globorotalia fohsi* s.l. Zone as it does at other sites. The first increase in the size of faunas that is not attributable to the vagaries of preservation occurs in 591B-12,CC, in the *Globorotalia mayeri* Zone. The six new entrants appearing at this time are all also found in abundance in the Pliocene at Site 590, but are most typical and abundant at sites underlying upwellings.

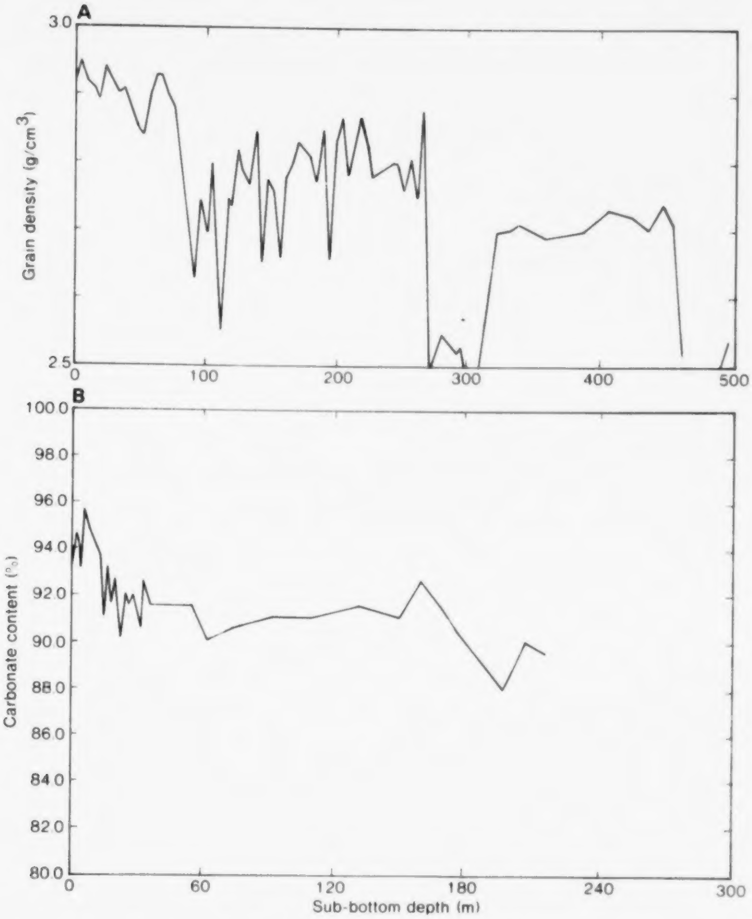


Figure 6. Grain density (A) and carbonate content (B) versus sub-bottom depth for Site 591.

At the base of the *Neogloboquadrina continuosa* Zone (591B-8,CC; 591-30 to 591-31,CC), large numbers of miliolid fragments and two species, *Pyrgo murrhina* and *Quinqueloculina seminulina*, occur for the first time. Faunas through the remainder of the Miocene are dominated by the miliolids and, in the *Globigerina nepenthes* Zone, by *Uvigerina hispido-costata*. This type of miliolid–uvigerinid fauna, including also *Melonis pompilioides* and several taxa more typical of Site 590, disappears at the top of the Miocene, but reappears in this area during the *Globorotalia tosaensis* Zone and continues into the Quaternary.

At the top of the Miocene (*Globorotalia conomiozea* Zone, 591-22,CC through 591-21) preservation deteriorates and the depleted benthic faunas contain only the most dissolution-resistant species and some miliolid fragments.

Lower Pliocene faunas (591-20,CC to 591-14) are well preserved and diverse; typical taxa include *Oridorsalis umbonatus, Heterolepa kullenbergi, P. murrhina*, and *Bulimina alazanensis*. The transition to the glacial fauna (*G. crassaformis/G. inflata*) shows a change in coarse-fraction content. Species changes include only the reintroduction of species already present in the Miocene at this site and variations in abundances of species common in the Pliocene. The miliolids decrease markedly in number through this interval.

The most obvious change in faunal content of the Pliocene occurs in the *G. tosaensis* Zone (591-10 to 591-9,CC) and in the *G. tosaensis–G. truncatulinoides* overlap interval (591-8 to 591-5,CC), when faunas again resemble those of the upper Miocene and include, as well, several species typical of shallower sites, such as *Anamalinoides globulosa, Cibicidoides pseudoungerianus, Cassidulina laevigata*, and *Pullenia quadriloba*.

Whereas most of the appearances/disappearances throughout this section are not considered to have been evolutionary events, it is interesting that the first appearance of *Uvigerina peregrina* occurs later at Site 591 (in the *G. puncticulata* Zone) than it did at the shallow Site 590, where it first occurs in the upper Miocene. This suggests that a form not generally associated in the Quaternary or Pliocene with intermediate waters first appeared at these shallower depths. The descent of uvigerinids from upper bathyal to deeper areas occurred several times during the history of the group.

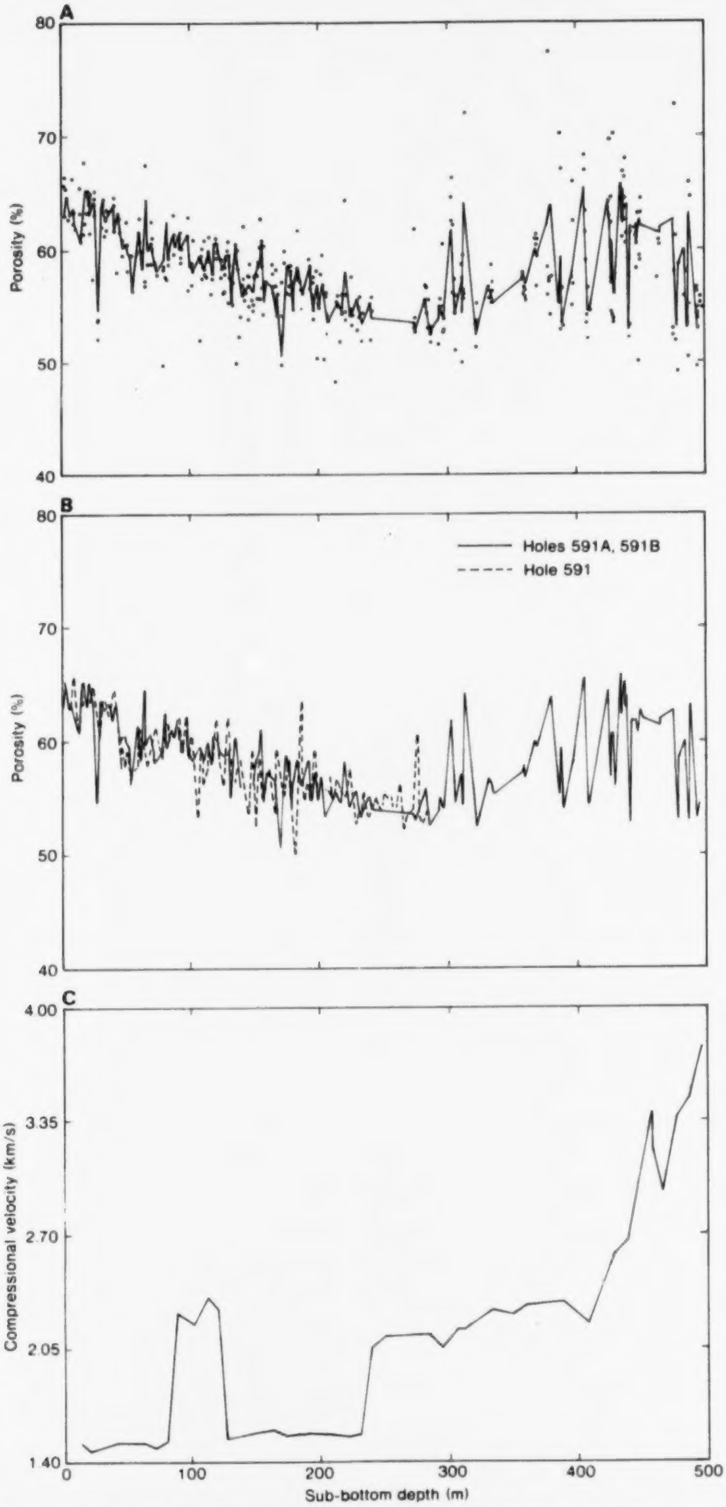


Figure 7. A. GRAPE porosity versus sub-bottom depth for Hole 591A. B. GRAPE porosity versus sub-bottom depth for Holes 591, 591A, and 591B. C. Compressional velocity versus sub-bottom depth for Site 591. D. Porosity versus compressional velocity for Hole 591A. E. Shear strength versus sub-bottom depth for Hole 591A. F. Porosity versus shear strength for Hole 591A. G. Acoustic impedance versus sub-bottom depth for Hole 591A.

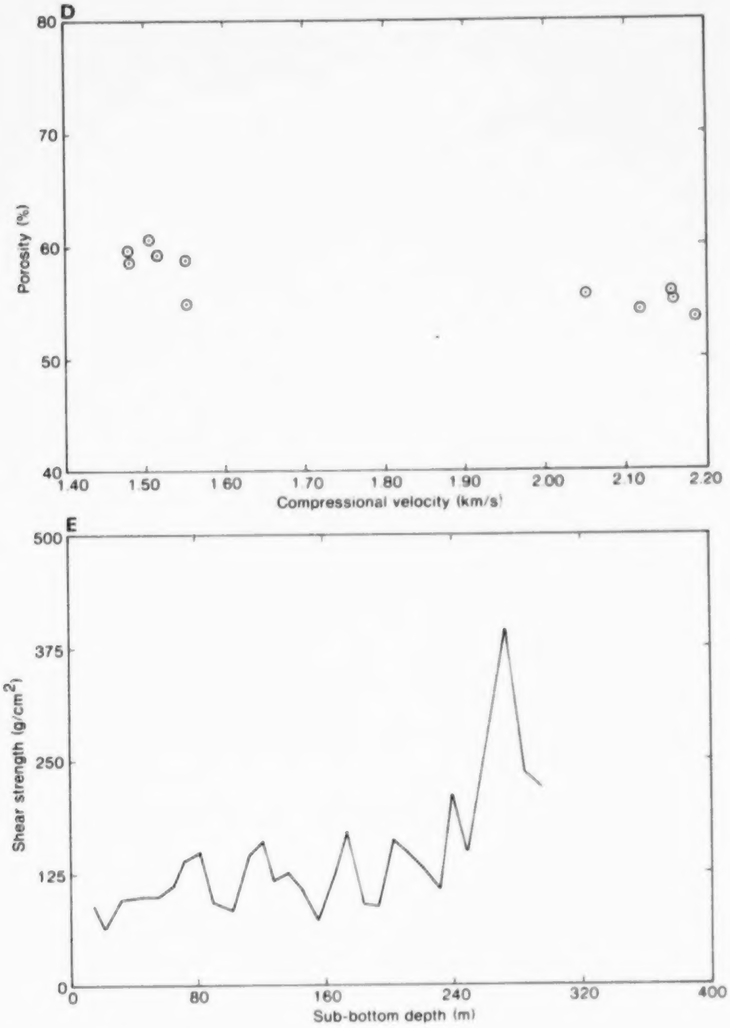


Figure 7. (Continued).

Calcareous Nannoplankton

Core-catcher samples along with sufficient additional samples to determine zonal boundaries accurately were examined for calcareous nannoplankton. All of the zonal indicators are present, with the exception of *Helicosphaera ampliaperta*. The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis*. Calcareous nannoplankton are abundant throughout the section at Site 591. Preservation is good in the Quaternary and Pliocene. In the Miocene, preservation deteriorates from moderate to poor, and in particular most of the discoasters are heavily overgrown.

Hole 591

Thirty-one cores were recovered from Hole 591, providing a complete nannoplankton zonation from late Quaternary to late Miocene.

Quaternary

Samples 591-1,CC to 591-2-3, 3-4 cm are placed in the late Pleistocene *Gephyrocapsa oceanica* Zone (NN20). Sample 591-2-5, 3-4 cm contains *Emiliania ovata* and is placed in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The presence of *E. ovata* together with *Calcidiscus macintyrei* in Samples 591-5-5, 3-4 cm to 591-6,CC places these samples in the lower subzone of the *E. ovata* Zone (NN19a).

Pliocene

The presence of *Discoaster brouweri* in Samples 591-7-1, 3-4 cm to 591-8-1, 3-4 cm places these samples in the late Pliocene *Discoaster brouweri* Zone (NN18). The late Pliocene *D. pentaradiatus* Zone (NN17) is represented only by Sample 591-8-3, 3-4 cm, based on the last occurrence of *Discoaster pentaradiatus*. The late Pliocene *D. surculus* Zone (NN16) is located by the last oc-

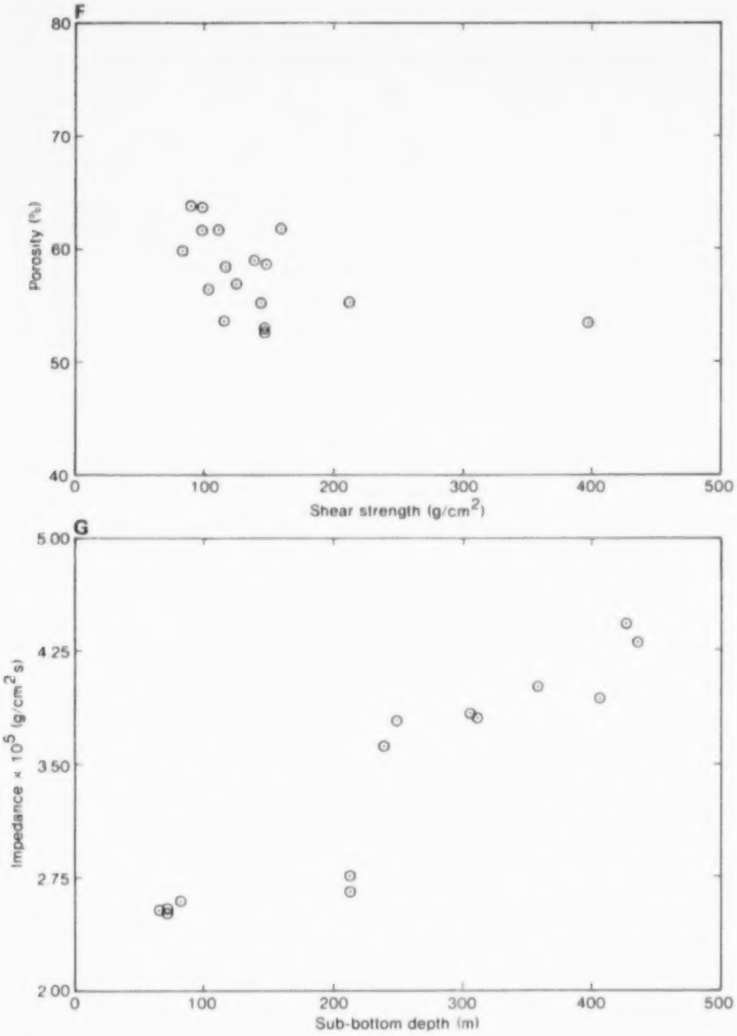


Figure 7. (Continued).

currence of *D. surculus* in Samples 591-8-5, 3–4 cm to 591-12-3, 3–4 cm, above the last occurrence of *Reticulofenestra pseudoumbilica*.

Samples 591-12-5, 3–4 cm to 591-16,CC above the last occurrence of *Amaurolithus tricorniculatus*, are placed in the early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). The co-occurrence of *D. asymmetricus* and *A. tricorniculatus* in Samples 591-17-1, 21–22 cm to 591-20,CC places these samples in the early Pliocene *Discoaster asymmetricus* Zone (NN14). The first occurrence of *Ceratolithus rugosus* in Sample 591-21-5, 3–4 cm places this sample and the overlying Sample 591-21-1, 3–4 cm in the early Pliocene *Ceratolithus rugosus* Zone (NN13).

Miocene

Samples 591-24-3, 3–4 cm, the last occurrence of *D. quinqueramus*, to 591-28-3, 3–4 cm, the first occurrence of *A. primus*, are placed in the upepr subzone of the late Miocene *D. quinqueramus* Zone (NN11b). Samples 591-28-5, 3–4 cm to 591-31,CC, the deepest core at Hole 591, are placed in the lower subzone of the *Discoaster quinqueramus* Zone (NN11a).

Hole 591A

Only the 31 core-catcher samples from the hole were examined, because this hole duplicated the zonation of Hole 591.

Hole 591B

Miocene

The first occurrence of *D. quinqueramus* in Sample 591B-4,CC places Samples 591B-1,CC to 591-4,CC in the lower subzone of the late Miocene *Discoaster quinqueramus* Zone (NN11a). The interval from Samples

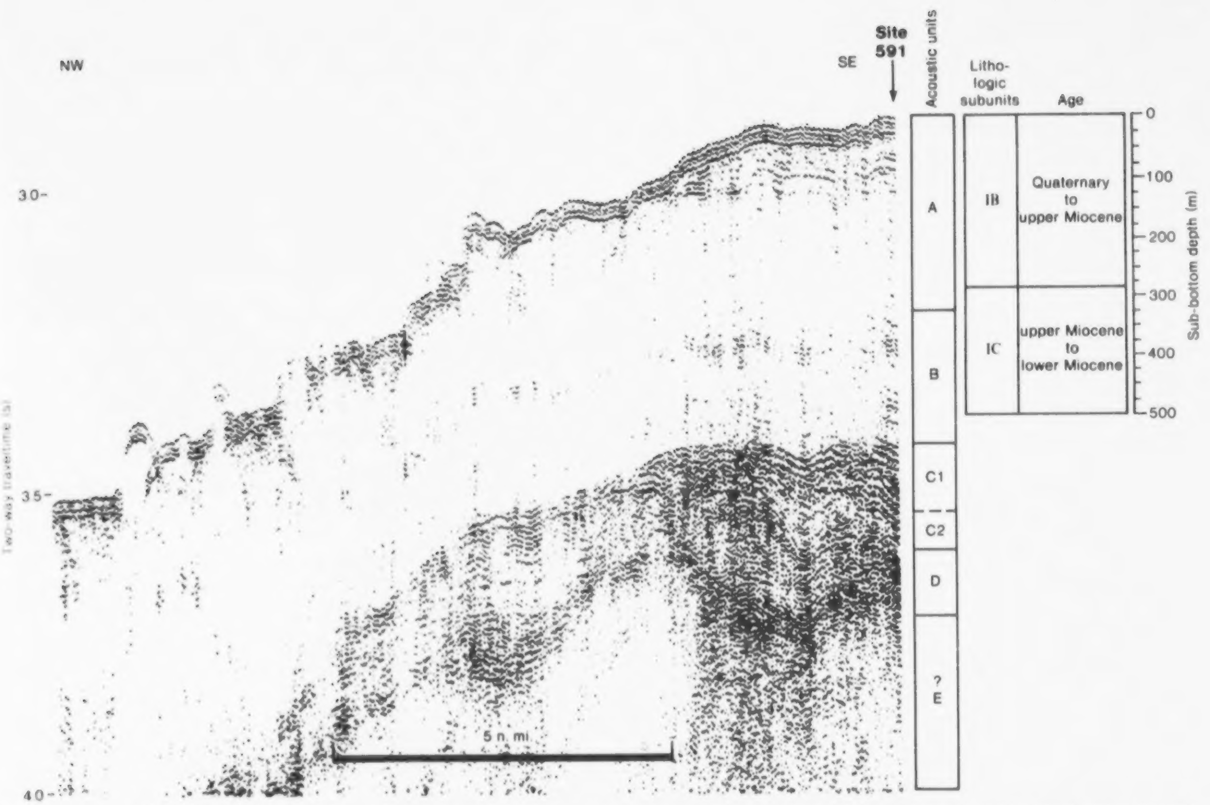


Figure 8. Comparison of acoustic units A–E with lithostratigraphic Subunits IA (not shown), IB, and IC cored at Site 591; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 2000 m/s.

591B-5-1, 3–4 cm to 591B-9-2, 4–5 cm, above the last occurrence of *D. hamatus* in Sample 591B-9,CC, is placed in the late Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus* in Samples 591B-9,CC to 591B-11-1, 4–5 cm places these samples in the middle Miocene *D. hamatus* Zone (NN9). Sample 591B-11,CC is placed in the middle Miocene *Catinaster coalitus* Zone (NN8). The interval from Samples 591B-12-1, 3–4 cm to 591B-12,CC, the first occurrence of *D. kugleri*, is placed in the middle Miocene *D. kugleri* Zone (NN7). The interval from Samples 591B-13-1, 3–4 cm to 591B-18-5, 3–4 cm, above the last occurrence of *Sphenolithus heteromorphus* in Sample 591B-18,CC, is placed in the middle Miocene *D. exilis* Zone (NN6). The presence of *S. heteromorphus* together with *D. exilis* in Samples 591B-8,CC to 591B-23,CC places these samples in the midle Miocene *Sphenolithus heteromorphus* Zone (NN5). ample 591B-24,CC possibly belongs in the early Mione *Helicosphaera ampliaperta* Zone (NN4).

iatoms and Silicoflagellates

Diatoms and silicoflagellates occur in fair numbers oughout most of the section, but the occurrences are avily masked by vast numbers of foraminifers and calreous nannoplankton. Fragments of diatoms and siliflagellates were noted in several routine smear slides om the late Pliocene down to the middle Miocene.

The residue of an acid-treated sample (591B-5,CC) of late Miocene age (nannoplankton Zone NN10) included representatives of the diatom genera *Hemidiscus*, *Thalassiosira*, and *Coscinodiscus*. The silicoflagellate assemblage of this particular sample is dominated by members of the *Dictyocha fibula* group (forms with horizontal apical bar) and *Distephanus polyactis*. Present also are *D. crux*, *D. speculum*, and *Mesocena circulus*. They are associated with sponge spicules and endoskeletal dinoflagellates.

Radiolarians

Fragments of radiolarians were found in smear slides from various levels, indicating the presence of this fossil group throughout most of the drilled section. In the residue of the acid-treated Sample 591B-5,CC radiolarians are rather common, but were not investigated in detail.

PALEOMAGNETISM

Preliminary NRM results were generally similar to those from previous sites. Sedimentation rates are somewhat higher than in nearby Site 590 and there was no evidence of a viscous component of magnetization. A magnetic polarity stratigraphy can be traced down to the end of the Gilbert Chron which is reproduced in the Hole 591A.

Hole 591 was subsampled at three specimens per section, Hole 591A at two specimens per section, and rota-

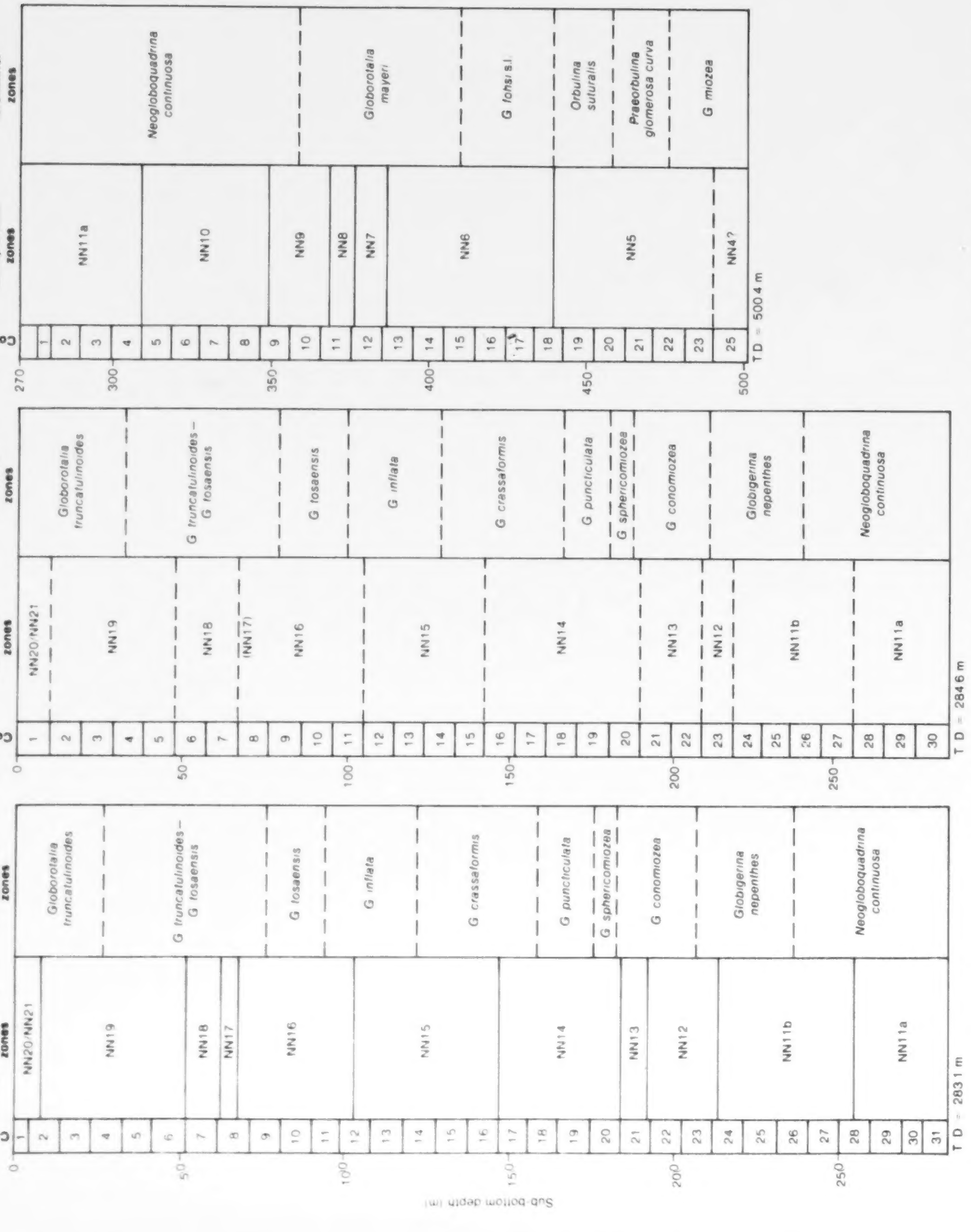


Figure 9. Correlation between calcareous nannoplankton and foraminifer zones in Hole 591, 591A, and 591B (radiolarians, though present in small numbers, were not investigated).

ry-drilled Hole 591B at one specimen per section. Apparent success rates with the Kuster orientation tool were 55 and 58% for Holes 591 and 591A. Laboratory NRM measurements have been completed on three specimens per section for the upper three cores from Holes 591 and 591A, and one specimen per section for the remaining cores from these two holes. The mean hole statistics are:

	Hole 591	Hole 591A
Geometric mean intensity (μG)	0.066	0.059
Scalar mean inclination (± 1 s.d.)	−9.1 ±43.7°	−7.2 ±44.0°
Axial dipole inclination	−50.9	
Mean angle between repeats	6.1°	6.7°

The ubiquitous and surficial high-intensity zone (1 to [illegible] μG) is almost completely confined to the first core in each hole. From about 5–20 m sub-bottom depth intensities are typically 0.1 μG and thereafter remain consistently low (typically a few × 10^{-2} μG). There is a general trend toward lower intensity with increasing depth. High-intensity spikes noted in Hole 591 are listed in Table 2.

The quality of the paleomagnetic record deteriorates increasingly as a function of depth and cannot be interpreted in terms of polarities with any confidence below about 110 m sub-bottom depth (the upper part of the Gilbert Chron, about 3.5 m.y. ago). The polarity stratigraphy for Hole 591 (Fig. 10) is duplicated in the adjacent HPC Hole 591A.

To assess the magnetic stability of these sediments, partial AF demagnetization tests were run on seven specimens from Hole 591 (Table 3). More strongly magnetized specimens where chosen deliberately, because the weaker ones rapidly became immeasurable when demagnetized. The upper sediments which preserve a polarity record give stable directions in fields up to at least 400 Oe (40 mT) and median destructive fields in the range 215 to 310 Oe (21.5 to 31 mT). Lower in the section median destructive fields ranged from 120 to 155 Oe, and directional stability was poorer—consistent directions were observed up to peak AF's of about 200 Oe. There was no evidence for a soft viscous component in any of the specimens, which agrees with the fact that the mean inclination for the section does not have a significant negative bias. Without a more extensive study it is not possible to establish the scale of any chemical overprinting: the present indication is that the remanence is essentially single-component and sufficiently stable to preserve a record of polarity reversals. Since measurements on the very weakly magnetized material are reproducible, the scatter in the data cannot be attributed predominantly to instrumental noise.

Table 2. High-intensity spikes at Site 591.

Sample (level in cm)	Depth (m)	Intensity (μG)
591-1-2, 80	2.30	7.419
591A-4-5, 40	34.80	2.371
591-8-1, 80	61.80	0.586
591-12-6, 75	107.65	0.597
591A-12-6, 40	113.10	0.248
591A-15-3, 40	136.50	0.234
591-16-4, 75	142.15	0.210
591-16-5, 75	143.65	0.273
591A-19-2, 40	172.40	0.369
591-20-3, 75	178.05	0.187
591A-20-1, 40	180.40	0.896
591A-24-3, 40	221.10	0.122
591-28-4, 75	255.55	0.168
591-28-5, 75	257.05	0.170

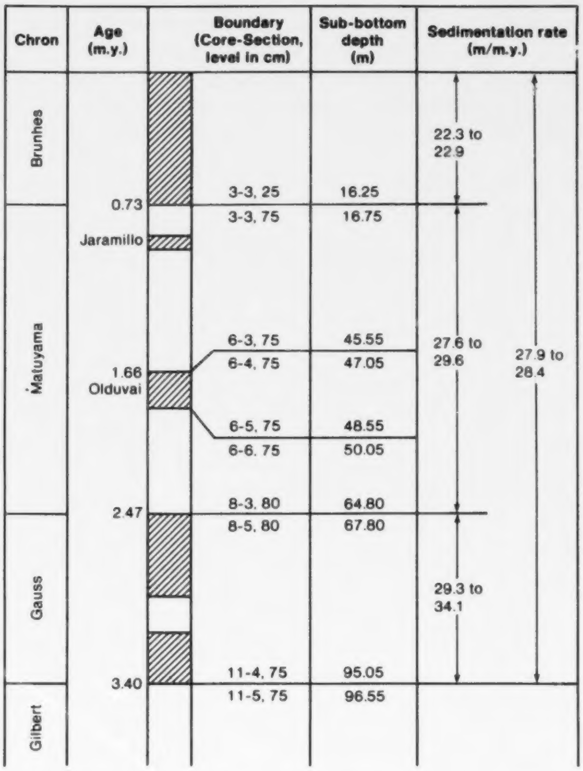


Figure 10. Magnetic polarity stratigraphy for the upper part of Hole 591.

Table 3. Summary of partial AF demagnetization results for Hole 591.

Core-Section (level in cm)	Depth (m)	J_0 (μG)[a]	MDF (Oe)	AF stability range (Oe)	Inclination variation
1-1, 25	0.25	5.395	255	0–400	±5°
2-2, 125	6.15	1.544	310	0–400	±5°
3-1, 125	14.25	0.364	215	0–500	±6°
3-4, 75	18.25	0.191	120	0–200 0–500	±14° ±24°
12-6, 75	107.65	0.424	120	0–150	±13°
20-3, 75	178.05	0.179	155	0–300	±6°
28-5, 75	257.05	0.165	135	0–500	±25°

Note: The range of demagnetizing field for a given range of inclination variation is shown in the last two columns.

[a] Initial NRM intensity.

SEDIMENTATION RATES

Sedimentation rates (Fig. 11) are based on calcareous nannoplankton boundaries and their absolute ages, as indicated in the Introduction. For better comparison, intervals taken for calculating the sedimentation rates are the same as for the previous sites.

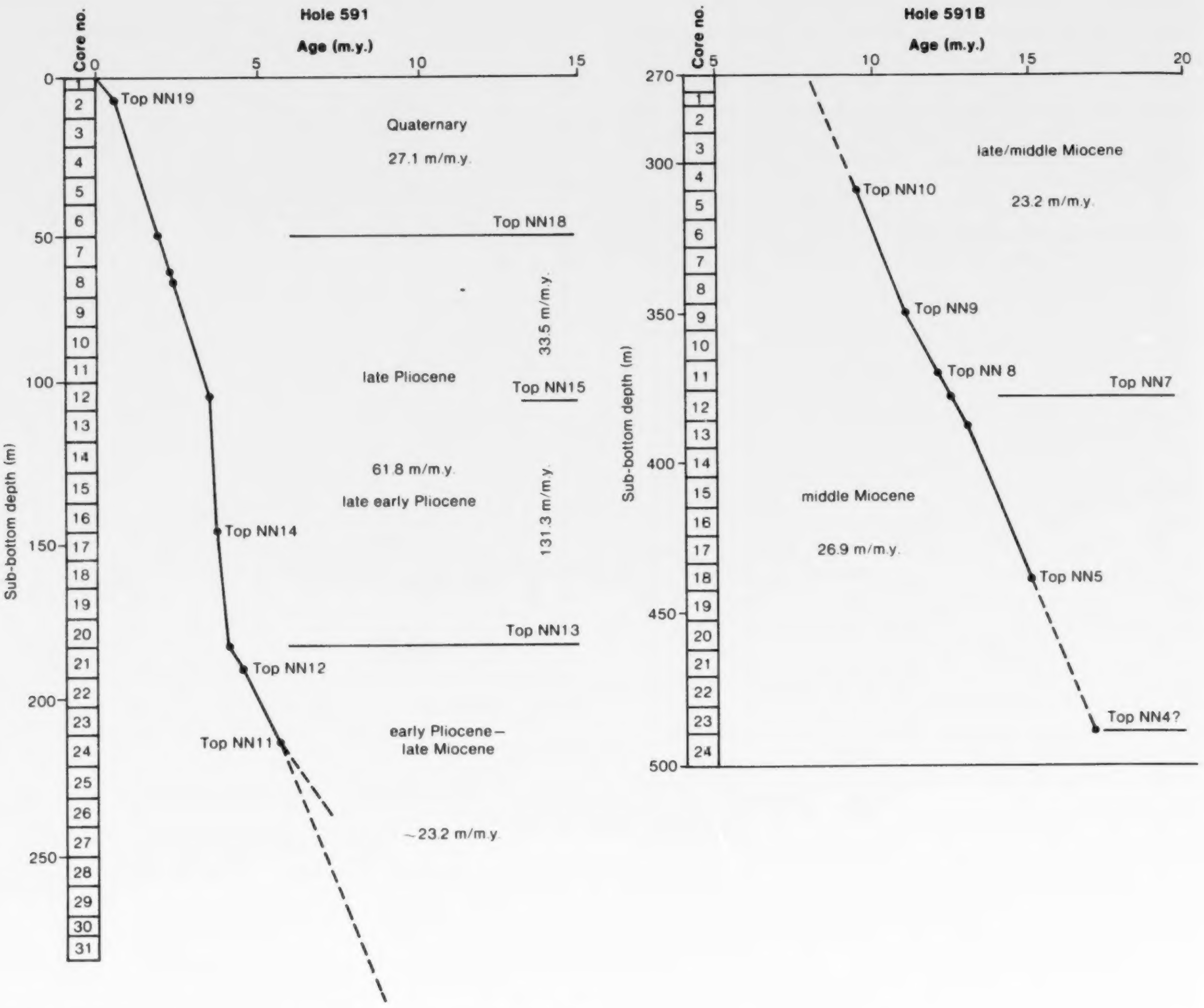


Figure 11. Sedimentation rates and datum levels in Holes 591 and 591B.

In the middle Miocene (Hole 591B, NN4 top to NN7 top), the sedimentation rate is based on four datum levels and is 26.9 m/m.y. for indurated calcareous sediments with minor siliceous constituents (Fig. 11B).

In the late middle Miocene to early Pliocene interval (Hole 591B, NN7 top, to Hole 591, NN13 top), the sedimentation rate is 23.2 m/m.y. and similar to that of the middle Miocene (Fig. 11A, B). This rate is based on seven datum levels.

Then a remarkable increase in the sedimentation rate occurs in the late early to late Pliocene, similar to that of Site 590. The sedimentation rate of calcareous sediments (foraminifer-bearing nannofossil ooze) for the entire interval between NN13 top and NN18 top in Hole 591 is 61.8 m/m.y., and is based on six datum levels. The strongest increase is found during deposition of Zones NN14 and NN15 (between 4.1 and 3.5 m.y. ago), where it increases to 131.3 m/m.y. In the late Pliocene (Hole 591, NN15 top to NN18 top), the sedimentation rate slows to 33.5 m/m.y. (Fig. 11A).

In the Quaternary (Hole 591, above NN18 top) the sedimentation rate drops further to a value of 27.1 m/m.y., which, however, is well above the 17.2 m/m.y. at Site 590.

SUMMARY AND CONCLUSIONS

Site 591 lies near the crest of a southern spur of the eastern part of the Lord Howe Rise at 31°35.06′S, 164°26.92′E and at a water depth of 2131 m. The spur extends outward into the New Caledonia Basin and is surrounded by turbidite fill to the east and south. The western edge of the spur is, in its norther part, separated from the main part of Lord Howe Rise by a valley that slopes southward, leading toward a ponded turbidite sequence which slopes toward the level of New Caledonia Basin. Thus the crest of the spur on which Site 591 is located is largely isolated from any influences of sediment transportation from the main part of Lord Howe Rise. The seismic profile exhibits a relatively simple transparent layer about 520 m thick above a distinct reflector which is considered to represent the regional unconformity associated with the Eocene/Oligocene boundary.

Site 591 was selected to provide a Neogene–late Paleogene stratigraphic succession at water depths intermediate (about 2200 m) between Site 590 (1299 m) and Site 206 (3196 m). A site at this intermediate depth was required to study changes in the vertical water mass structure of the southwest Pacific Ocean during the Neogene. These three sites, in combination, will provide an opportunity to carry out detailed studies of changes in the intermediate water masses between 1000 and 3000 m water depth. Site 591 is located midway between Sites 590 and 206, providing a compact suite of sites. Northward movement of the Indo–Australian Plate has carried Site 591 about 4–5° of latitude from about 35°S in the early Miocene to its present-day position near 31°30′S. Thus the Neogene sedimentary history at this site has been related in part to its northward movement away from the temperate region and the zone of westerly winds.

Site 591 consists of three holes: Hole 591 was continuously cored with the HPC from 0–283.1 m sub-bottom; Hole 591A was continuously cored with the HPC from 0–246.5 m and rotary cored with the XCB from 246.5–284.6 m; and Hole 591B was continuously cored using conventional rotary coring from 270.6–500.4 m sub-bottom. Cores recovered with the first HPC are relatively undisturbed; those using the second HPC are slightly more disturbed because of rough sea conditions. The cores recovered using conventional rotary coring exhibit mixed quality; quite disturbed in the upper part of the section although recovery was high; moderate recovery in the middle part of the sequence; and good quality cores with moderarte to low recovery rates in the lowest part of the sequence. The extended core barrel did not function successfully at this site.

The sequence is made up of one lithostratigraphic unit represented mostly by foraminifer-bearing nannofossil ooze or foraminifer-rich nannofossil ooze. Site 591 is a continuous sequence from the late early Miocene (17 m.y.) to the Quaternary. The HPC part of the sequence is complete from early late Miocene (11 m.y.) to the Quaternary. The biostratigraphy is complete with no apparent hiatuses. A paleomagnetic polarity stratigraphy has been identified down to the late Gilbert Chron (about 3.5 m.y.). Like Site 590, this site exhibits high sedimentation rates (uncorrected) ranging from 23 m/m.y. to 131 m/m.y.

Biosiliceous components are occasionally present in ace amounts, and exhibit slightly higher abundances the early Miocene to early late Miocene. Siliceous com- nents consist mainly of fragments of radiolarians, dia- ms, and sponge spicules, and silicoflagellates appear the latest Miocene (Cores 591-21 and 591A-23).

Nonbiogenic components comprise only a very small portion of the sediment. Micritic carbonate signifi- ntly increases near the bottom of the section in the early and early middle Miocene. In the middle middle Miocene, trace quantities of clear volcanic glass occur throughout the sequence. Ash layers are present at certain intervals as well as very common light greenish gray laminae which possibly represent devitrified layers of volcanic ash. These laminae are commonly associated with underlying gray laminae of iron sulfides.

The sequence at Site 591 is divided into three subunits based on color, on the relative abundance of foraminifers and calcareous nannofossils and on the degree of lithification (Fig. 12).

Subunit IA extends from the seafloor to 0.62 m sub-bottom in Hole 591 and to 0.50 m in Hole 591A. This subunit is late(?) Quaternary in age. The sediment is yellowish gray to pale yellowish brown and consists of a foraminifer-bearing nannofossil ooze. Subunit IA corresponds to the zone of oxidation which was found in all of our sites.

Subunit IB extends from the base of the oxidized layer to 289.8 m sub-bottom (Quaternary to upper Miocene). The sediments, light gray in color, range from a foraminifer-bearing nannofossil ooze to a nannofossil ooze. Frequent greenish gray levels occur within this subunit, which contain slightly more foraminifers than the dominant light gray oozes.

Subunit IC extends from 289.8 m sub-bottom to the bottom of Hole 591B (500.4 m sub-bottom). This subunit is upper Miocene to lower Miocene in age. The sediments, very light gray to light greenish gray, range from a foraminifer-bearing nannofossil chalk to a nannofossil chalk. Clear recrystallization occurs below 300 m. Sediment becomes very hard and recrystallization is widespread below 452 m (earliest middle Miocene).

Diagenetic alteration of the microfossil sequence appears at Site 591 in younger sediments than at Site 590, because of the higher sedimentation rates at Site 591. Foraminifer recrystallization is already well advanced by the early middle Miocene, and calcareous nannofossils exhibit signs of overgrowths by the early Pliocene. The higher rates of sedimentation at Site 591 have allowed finer stratigraphic resolution than at Site 590. The planktonic faunas are identical to those from nearby Site 590; however, three biostratigraphic zones not recognized at Site 590 were recovered at Site 591. These are the early Pliocene *Globorotalia sphericomiozea* Zone, the *Orbulina suturalis* Zone of the early middle Miocene, and the *Praeorbulina glomerosa curva* Zone of the early Miocene. The presence of these relatively thin zones is attributed to very high sedimentation rates at Site 591.

Radiolarians, diatoms, and silicoflagellates were present but uncommon in most cores throughout the section. They are common in the coarse fractions of sediments younger than early middle Miocene. The greater water depth of Site 591 somehow favors the preservation of some of the siliceous biogenic fraction compared with the nearby, shallower-water Site 590, which has almost no siliceous biogenic components. A number of evolutionary sequences within the planktonic foraminifers are clearly exhibited in this expanded sequence which, in general, provides excellent opportunities for high-resolution microfossil and stable isotopic work, particularly in the well-preserved upper Miocene through Quaternary section.

Site 591 is intermediate in its vertical depth profile (2131 m) between Sites 590 and 206; thus the benthic foraminifers are of considerable interest. Benthic fora-

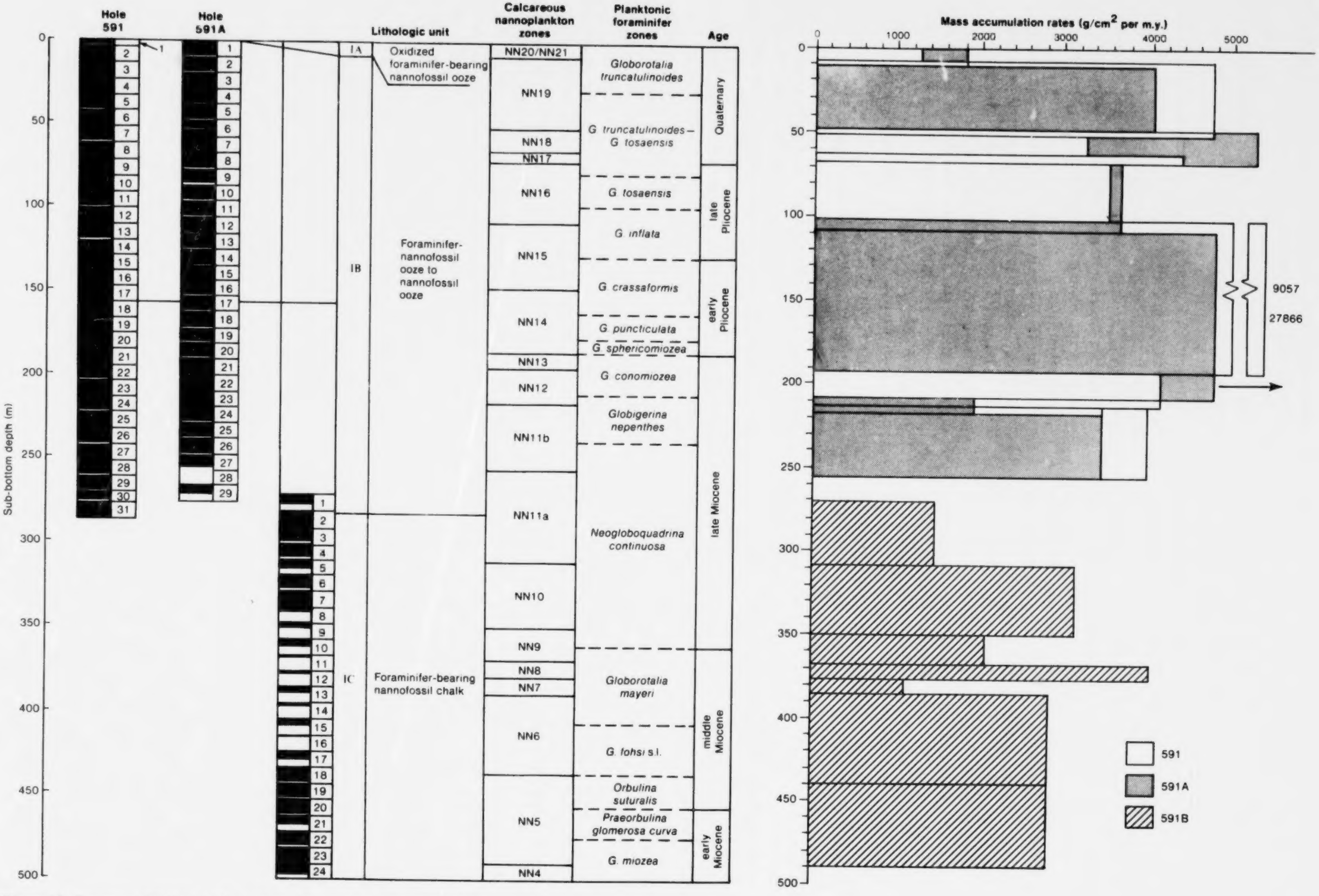


Figure 12. Summary lithology, biostratigraphy, and mass accumulation rates at Site 591 (recovery in black).

miniferal faunas are well preserved from the Quaternary through the late Miocene; earlier than that, faunas are impoverished; in the middle Miocene, recrystallization of the individuals increases and by the early Miocene few, if any, forms could be recognized because of the recrystallization and cementation. The benthic faunas contain many of the same species found at Site 590; however, some important differences reflect distinct paleoceanographic histories at these different water depths. The paleoceanographic changes include both upward and downward migration of some benthic foraminifers. Assemblages typical of upwelling zones appear in the middle Miocene.

Site 591 exhibits a valuable tephrochronology based on many layers and laminae which are inferred to be altered volcanic ash layers. These are compiled in Figure 4 for each of the three holes. Figure 4B shows a compilation for all Site 591 holes and also provides average ash layer densities per unit of core. These data clearly show that there have been a number of episodes of volcanic explosivity separated by more quiescent intervals. Intervals of more active volcanism are as follows: 17–14 m.y., latest early Miocene to middle Miocene; 10.5–9 m.y., early late Miocene; 5.4–4 m.y., latest Miocene to early Pliocene; 1.8–0.5 m.y., early to middle Quaternary.

Middle Miocene volcanic explosivity may be more extensive, but this is difficult to determine because of poor core recovery throughout this interval. The episodes of increased explosive volcanicity are separated by periods of relative quiescence, which include much of the Pliocene and late Miocene. This history is similar to that compiled by Kennett et al. (1977) for the southwest Pacific region and is also similar to the trends exhibited in a global compilation.

Paleoenvironmental History of Site 591

The Neogene sediments at Site 591 were deposited in a paleoenvironmental setting similar to that of nearby Site 590. Both of these sites exhibit similar stratigraphic records and paleoenvironmental histories. However, the greater water depth of Site 591 and its location upon an isolated spur of Lord Howe Rise have created a number of important paleoceanographic differences, especially in the intermediate waters.

During the late early to middle Miocene, the site was located about 4 to 5° of latitude further south than its present-day position near 31°35′S. This would have placed it within the zone of westerly winds and in temperate latitudes, a reconstruction which is supported by the distinctly temperate planktonic foraminifer assemblages in the early Neogene. Foraminifer-bearing nannofossil oozes were laid down during this time interval as well as in the early late Miocene. During the early middle to early late Miocene, siliceous biogenic materials were preserved in the sequence, although they are fairly uncommon. At other times they are much less common. Their increased abundance during the interval must reflect decreased dissolution. Sedimentation rates were moderately high during the late early to middle Miocene, with values of between 23 and 27 m/m.y.

Explosive volcanicity seems to have been quite intense in the source region between 17 and 14 m.y. ago, judging from the large number of volcanic ash layers. This episode of increased volcanicity may have continued through the middle Miocene, but poor core recovery prevented comparable analysis.

During the late middle Miocene, a number of new benthic foraminiferal species appeared, heralding important changes in bottom waters at this site. These changes occurred later than the well-known earlier middle Miocene changes known from other areas (Woodruff et al., 1981) that have been linked to bottom-water changes that took place during the accumulation of the east Antarctic ice sheet.

During the early late Miocene, the mode of sedimentation changed to more pure nannofossil oozes, which lasted until the mid-early Pliocene. Rates of sedimentation remained much the same at about 23 m/m.y.

The benthic foraminifer assemblages show important changes in the early late Miocene when miliolids become more important. they showed further change during the latest Miocene, when the assemblage became dominated by dissolution-resistant forms. This low-diversity assemblage heralds further important changes in the character of the bottom waters; it is associated with increased global glaciation. This represents the time of the Messinian "salinity crisis" of the Mediterranean Basin. The latest Miocene planktonic foraminiferal assemblages at Site 591 are typically cool, as they are also at Site 590. More foraminifer-rich sediments were laid down during a number of brief intervals during the latest Miocene, perhaps reflecting greater winnowing activity of bottom currents.

In this region the late Miocene is bracketed near the beginning and end with episodes of increased explosive volcanicity. These occur at about 10.5 to 9 and 5.4 to 4 m.y. ago, respectively. These episodes are separated by an especially quiescent period.

The beginning of the Pliocene is marked by a return of warmer-water planktonic foraminiferal assemblages. By the middle early Pliocene, sediment deposition again changed from rather pure nannofossil ooze to foraminifer-bearing nannofossil oozes. At the same time, there occurred a remarkable increase in sedimentation rates to 131 m/m.y. during the interval between 4 and 3.5 m.y. This increase almost certainly is created by an important increase in biogenic productivity. Explosive volcanic activity seem to have been relatively quiet during this interval, although the extremely high biogenic sedimentation rates may have masked any such activity.

During the late Pliocene, sedimentation rates decreased markedly to a still high rate of 33 m/m.y. This does not seem to coincide with any distinct change in the lithofacies. Explosive volcanism remained quiescent. As at all other sites, the benthic foraminiferal assemblages at Site 591 changed during the late Pliocene, when forms were reintroduced that had occurred through the Miocene. The earliest of these events were associated with global climatic changes about 3 m.y. ago related to major global climate cooling. Further and more important changes occurred later in the late Pliocene, probably in response to the initiation of Northern Hemisphere ice-sheet formation.

By the Quaternary, rates of sedimentation had further decreased to 27 m/m.y. Explosive volcanic activity was further renewed at this site in the Quaternary, as in many other circum-Pacific area.

As at other sites cored during Leg 90, the youngest sediments form an oxidized veneer at and close to the ocean floor.

The sedimentation rates calculated for Site 591 are mostly rather normal for carbonate biogenic oozes in shallow waters. The Pliocene rates of 131 m/m.y. are, however, extremely high and unexpected. High rates (57 m/m.y.) also mark the Pliocene of Site 590. We consider that these high rates are due to high productivity of calcareous biogenic material, a phenomenon now known in the late Neogene at three sites in this area (590, 591, and 206). It is possible that increased biogenic productivity is related to the poorly known Subtropical Divergence that crosses the Tasman Sea at the latitude of these three sites. Rates are much lower at the sites drilled to the north of Lord Howe Rise (Site 588) and to the south (Site 592). However, high rates have also been repeated for the Pliocene (early Pliocene, 40 m/m.y.; late Pliocene, 51 m/m.y.) of Site 289 on the Ontong-Java Plateau (Andrews, Packham, et al., 1975). We have now dismissed the possibility that the high sedimentation rates in the Pliocene are due to secondary reworking of material from elsewhere. This is due to the isolated location of Site 591 near the crest of a spur of Lord Howe Rise and to an absence of any clearly reworked material in the section.

REFERENCES

Andrews, J. E., Packham, G., et al., 1975. *Init. Repts. DSDP*, 30: Washington (U.S. Govt. Printing Office).

Bender, M. L., and Keigwin, L. D., 1979. Speculations about the upper Miocene change in abyssal Pacific dissolved bicarbonate $\delta^{13}C$. *Earth Planet. Sci. Lett.*, 45:383-393.

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Burkov, V. A., 1966. Structure and nomenclature of Pacific Ocean currents. *Oceanology*, 6(1). [English translation from *Okeanologiia*, 6(1).]

Douglas, R. E., and Woodruff, F., 1981. Deep Sea benthic foraminifera. *In* Emiliani, C. (Ed.), *The Sea* (Vol. 7): New York (John Wiley), 1233-1327.

Haq, B. U., Worsley, T. R., Burckle, L. H., Douglas, R. G., Keigwin, L. D., Jr., et al., 1980. Late Miocene marine carbon-isotopic shift and synchroneity of some phytoplanktonic biostratigraphic events. *Geology*, 8:427-431.

Keigwin, L. D., Bender, M. L., and Kennett, J. P., 1979. Thermal structure of the deep Pacific Ocean in the early Pliocene. *Science*, 205:1386-1388.

Kennett, J. P., 1978. The development of planktonic biogeography in the southern ocean during the Cenozoic. *Mar. Micropaleontol.*, 3: 301-345.

Kennett, J. P., McBirney, A. R., and Thunell, R. C., 1977. Episodes of Cenozoic volcanism in the circum-Pacific region. *J. Volcan. Geothermal Res.*, 2:145-163.

Loutit, T. S., and Kennett, J. P., 1979. Application of carbon isotope stratigraphy to late Miocene shallow marine sediments, New Zealand. *Science*, 204:1196-1199.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports, Scripps Institution of oceanography, La Jolla, California.

Shackleton, N. J., and Kennett, J. P., 1975. Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: oxygen and carbon isotope analysis in DSDP Sites 277, 279 and 281. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 743-755.

Shackleton, N. J., and Opdyke, N. D., 1977. Oxygen isotope and paleomagnetic evidences for early Northern Hemisphere glaciation. *Nature*, 270:216-219.

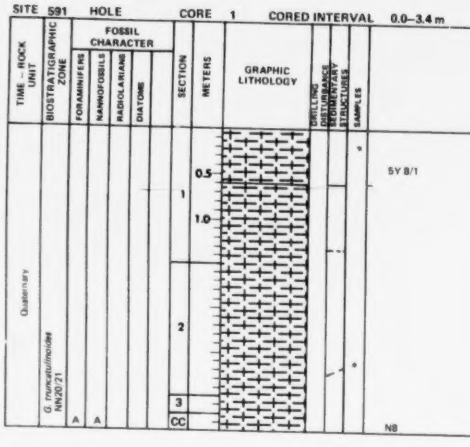
Vincent, E., Killingley, J. S., and Berger, W. H., 1980. The magnetic Epoch-6 carbon shift: A change of the oceans' $^{13}C/^{12}C$ ratio 6.2 m.y. ago. *Mar. Micropaleontol.*, 5:185-203.

Willcox, J. B., Symonds, P. A., Hinz, K., and Bennett, D., 1980. Lord Howe Rise, Tasman Sea—preliminary geophysical results and petroleum prospects. *B.M.R. J. Aust. Geol. Geophys.*, 5:225-236.

Woodruff, F., Savin, S. M., and Douglas, R. G., 1981. Miocene stable isotope record: a detailed deep Pacific Ocean study and its paleoclimatic implications. *Science*, 212:665-668.

Date of Acceptance: 1 December 1983

SITE 591 HOLE CORE 1 CORED INTERVAL 0.0–3.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN20/21
A
A
1
2
3
CC
0.5
1.0
5Y 8/1
N8

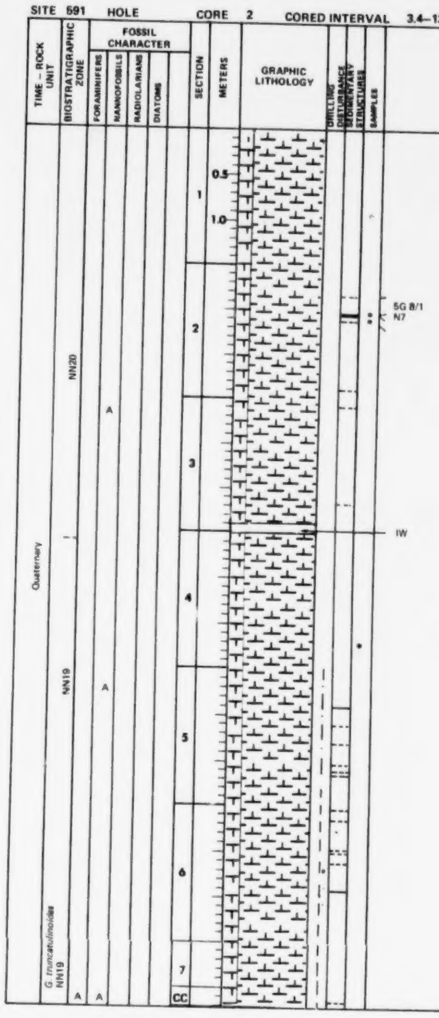
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, yellowish gray (5Y 8/1, top 62 cm) and very light gray (N8), soft, with burrow mottles of moderate yellow green (5GY 7/4) spotted by iron sulfides of light gray (N6–N7).

SMEAR SLIDE SUMMARY:

	1, 25	2, 110
	D	D
Texture:		
Sand	C	R
Silt	C	A
Clay	D	D
Composition		
Quartz	R	T
Heavy minerals	R	T
Clay	R	–
Pyrite	T	T
Foraminifers	A	A
Calc. nannofossils	D	D
Diatoms	T	T
Sponge spicules	T	–

SITE 591 HOLE CORE 2 CORED INTERVAL 3.4–13.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN20
NN19
G. truncatulinoides
NN19
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 8/1
N7
IW

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to white (N9), soft, with light greenish gray (5GY 8/1) zone and double colored bands of greenish (5GY 8/1) and light (N7) gray.

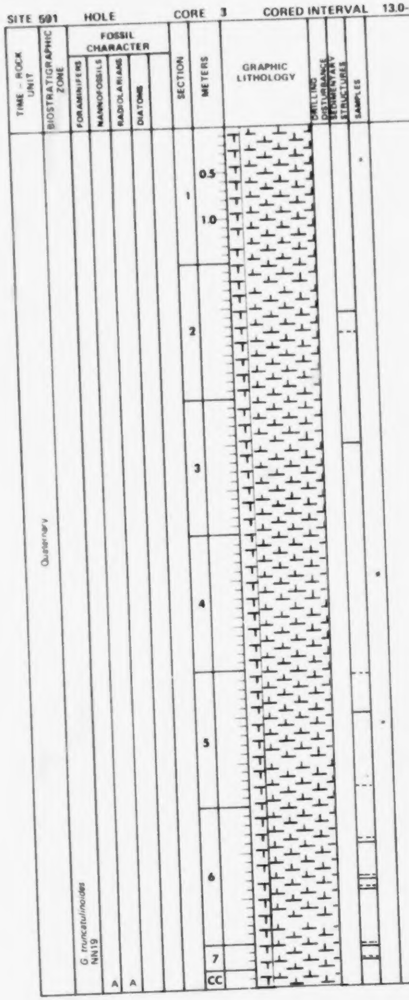
Ash layer (totally 25 cm in thickness) at about 55 cm of Section 2, clear, light gray (N7), 4 cm in thickness.

Light gray (N7) or light greenish gray (5GY 8/1) laminae occur in the lower part of the core (Sections 5, 6).

SMEAR SLIDE SUMMARY:

	1, 90	2, 45	2, 56	4, 120
	D	M	M	D
Texture:				
Sand	T	T	C	T
Silt	C	R	A	R
Clay	D	D	R	D
Composition:				
Quartz	T	T	R	T
Mica	T	T	T	T
Heavy minerals	T	T	–	T
Clay	R	R	–	R
Volcanic glass	–	C	D	T
Pyrite	T	T	–	T
Zeolite	–	T	–	–
Carbonate unspec.	T	–	–	–
Foraminifers	C	C	R	C
Calc. nannofossils	D	D	R	D

SITE 591 HOLE CORE 3 CORED INTERVAL 13.0–22.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

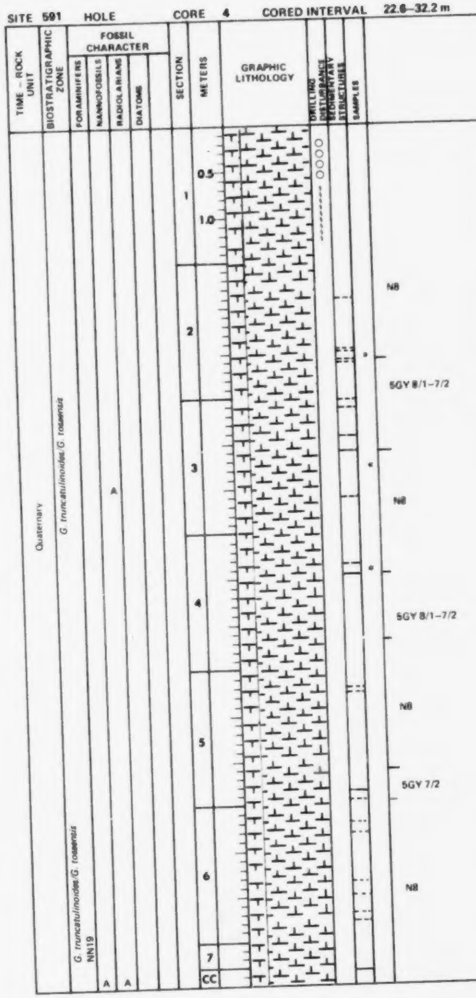
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) predominant, with gray (N6–7) or grayish yellow green (5GY 7/2) burrow mottles. Two tone colored laminae common in the lower sections. Dots and/or specks of iron sulfides.

SMEAR SLIDE SUMMARY

	1, 40 D	4, 48 M	5, 80 D
Texture			
Sand	T	C	R
Silt	C	C	C
Clay	D	A	D
Composition			
Quartz	T	–	T
Mica	T	–	–
Heavy minerals	T	R	T
Clay	R	R	R
Pyrite	T	C	T
Carbonate unspec.	T	–	–
Foraminifers	C	A	C
Calc. nannofossils	D	A	D

SITE 591 HOLE CORE 4 CORED INTERVAL 22.6–32.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
G. truncatulinoides/G. tosaensis
NN19
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 8/1–7/2
N8
5GY 8/1–7/2
N8
5GY 7/2
N8

LITHOLOGIC DESCRIPTION

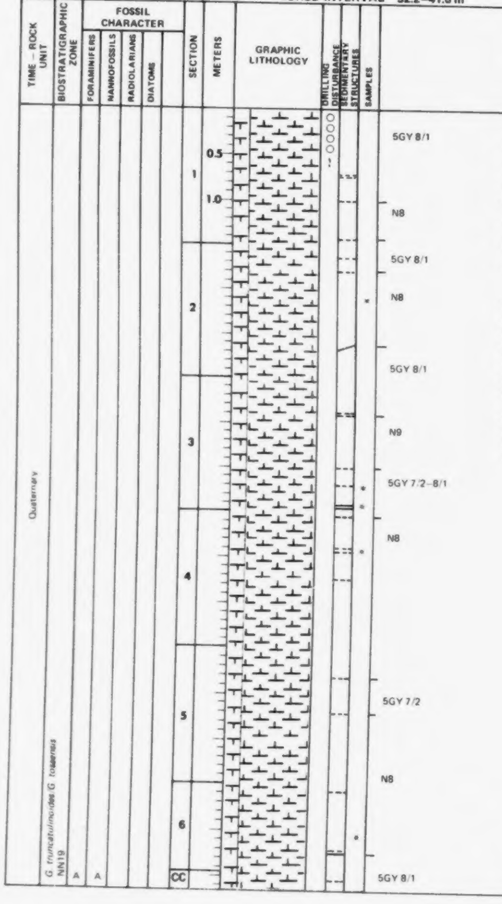
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, color alternation of greenish gray (5GY 7/2–5GY 8/1) and very light gray (N8), no significant difference of composition between the two colors.

Commonly, mottles and specks of gray (N6–N7) and yellowish to greenish gray (5GY 7/2 to 5GY 8/1); dark gray (N4–6) iron sulfides dots and streaks.

SMEAR SLIDE SUMMARY:

	2, 110 D	3, 80 D	4, 46 M
Texture:			
Sand	R	T	R
Silt	C	R	R
Clay	D	D	D
Composition:			
Quartz	T	T	T
Mica	–	T	–
Heavy minerals	T	T	T
Clay	T	T	–
Pyrite	T	T	T
Zeolite	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 591 HOLE CORE 5 CORED INTERVAL 32.2–41.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19
A
A
0.5
1.0
1
2
3
4
5
6
CC
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N9
5GY 7/2–8/1
N8
5GY 7/2
N8
5GY 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, predominantly very light gray (N8) and partly grayish yellow green (5GY 7/2), soft.

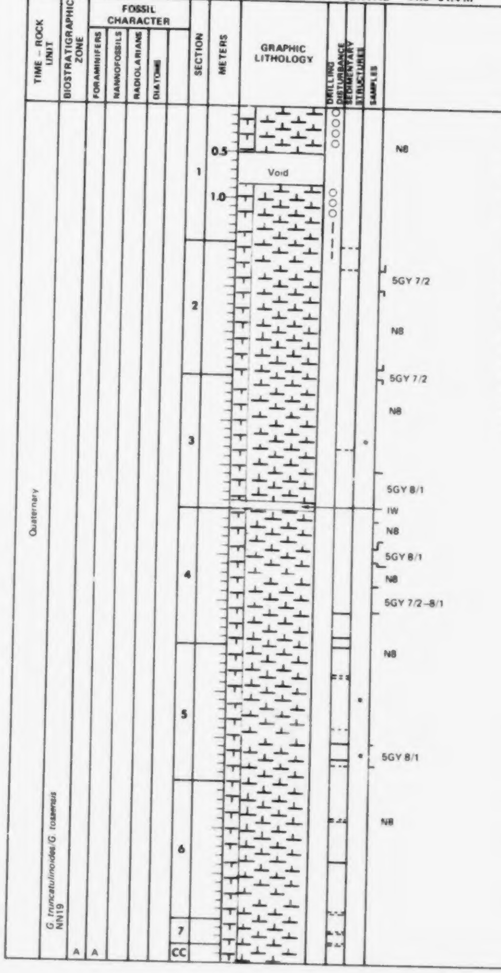
Two-tone colored bands of light gray (N7) and light greenish gray (5G 8/1) are common throughout.

Volcanic ash layer at the bottom of Section 3, clear dark greenish gray (5GY 6/2).

SMEAR SLIDE SUMMARY:

	2, 60 D	3, 126 M	3, 144 M	4, 46 M	6, 60 D
Texture:					
Sand	R	R	C	T	T
Silt	R	R	C	R	C
Clay	D	D	A	D	D
Composition:					
Quartz	T	T	R	T	T
Mica	T	–	–	T	T
Heavy minerals	T	T	T	T	T
Clay	R	T	T	T	T
Volcanic glass	–	R	C	–	–
Pyrite	T	T	T	T	–
Foraminifers	C	C	C	C	C
Calc. nannofossils	D	D	A	D	D

SITE 591 HOLE CORE 6 CORED INTERVAL 41.8–51.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19
A
A
0.5
1.0
Void
1
2
3
4
5
6
7
CC
N8
5GY 7/2
N8
5GY 7/2
N8
5GY 8/1
IW
N8
5GY 8/1
N8
5GY 7/2–8/1
N8
5GY 8/1
N8

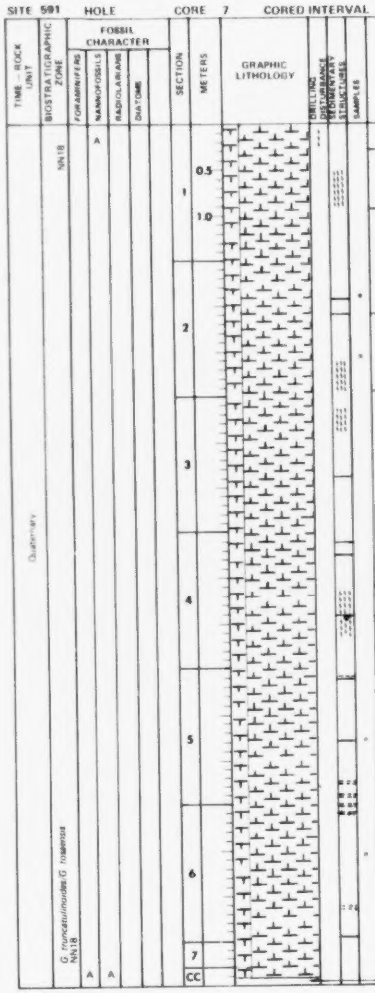
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft; color: alternation of predominant very light gray (N8) and light greenish gray (5GY 7/2–8/1) with numerous laminae, both lighter and darker; and with band, streaks and specks of iron sulfides of dark gray (N4–6).

SMEAR SLIDE SUMMARY:

	3, 70 D	5, 54 M	5, 122 D
Texture:			
Sand	T	R	T
Silt	R	C	C
Clay	D	D	D
Composition:			
Quartz	–	T	–
Mica	T	T	T
Heavy minerals	T	–	T
Clay	T	–	–
Volcanic glass	T	–	–
Pyrite	–	–	T
Carbonate unspec.	–	–	T
Foraminifers	C	C	R
Calc. nannofossils	D	D	D

SITE 591 HOLE CORE 7 CORED INTERVAL 51.4–61.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN18
G. truncatulinoides/G. tosaensis
NN18
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/1
N8–9
5GY 8/1–7/2
N8
5G 7/1
N8
5GY 7/2
N8
Void

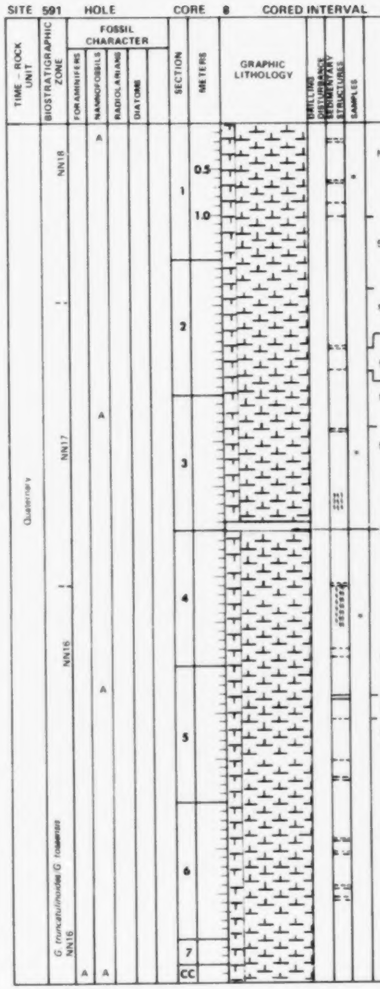
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, predominantly very light gray (N8), but partially greenish gray (5GY 7/2–8/1) where bioturbation is present. Moderately bioturbated, especially at the middle of Section 4 (lots of mud chunks).

SMEAR SLIDE SUMMARY:

	2, 50 D	2, 108 M	5, 89 M	6, 50 D
Texture				
Sand	T	T	R	T
Silt	C	C	R	C
Clay	D	D	D	D
Composition:				
Quartz	–	T	T	T
Feldspar	T	–	–	–
Mica	T	T	T	T
Heavy minerals	T	T	R	T
Clay	T	T	R	R
Pyrite	T	T	T	R
Carbonate unspec.	–	–	–	T
Foraminifers	C	C	C	C
Calc. nannofossils	D	D	D	D

SITE 591 HOLE CORE 8 CORED INTERVAL 61.0–70.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN18
NN17
NN16
G. truncatulinoides/G. tosaensis
NN16
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
5GY 8/1
N8–9
5GY 7/2–8/1
N8–9
5GY 7/2–8/1
IW
N8
5GY 7/2
N8
N9

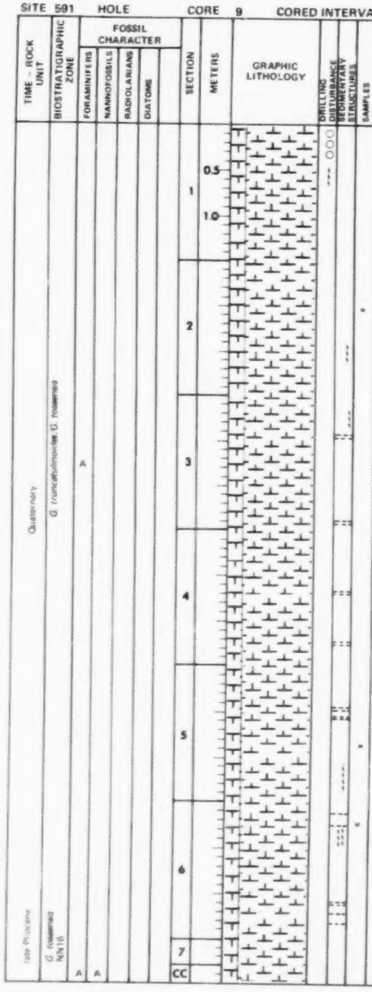
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft; color alternation of very light gray (N8–N9) and greenish gray (5GY 7/2–5GY 8/1), with burrow mottles and pyritized specks. Double colored laminae common.

SMEAR SLIDE SUMMARY:

	1, 60 D	3, 80 D	4, 83 M
Texture			
Sand	R	R	T
Silt	R	R	C
Clay	D	D	D
Composition:			
Quartz	T	T	T
Mica	T	T	T
Heavy minerals	T	T	T
Clay	T	–	R
Pyrite	T	T	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Sponge spicules	–	T	–

SITE 591 HOLE CORE 9 CORED INTERVAL 70.6–80.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
late Pliocene
G. truncatulinoides/G. tosaensis
G. tosaensis
NN16
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0

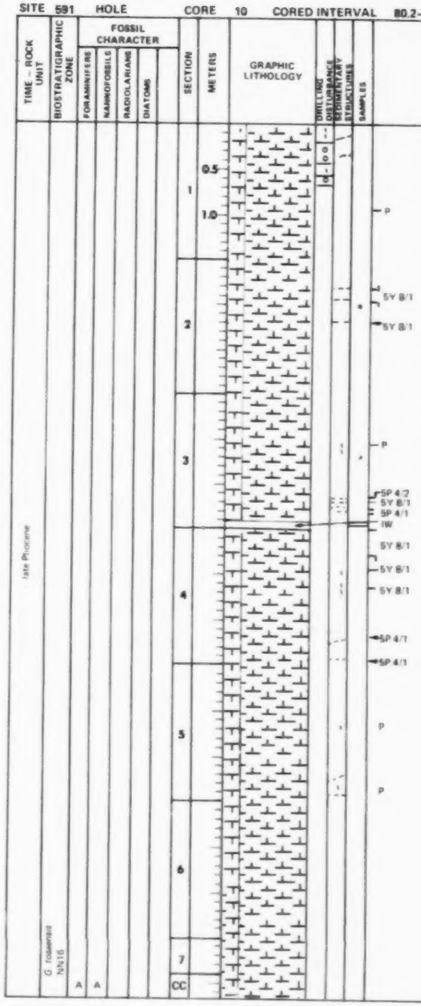
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light greenish gray (5GY 8/1), soft, with burrow mottles (yellowish gray (5Y 8/1)) and several laminae of two-tone color of light greenish gray (5G 8/1) and light gray (N7). Pyritized specks common.

SMEAR SLIDE SUMMARY:

	2, 50	5, 80	6, 20
	D	D	M
Texture:			
Sand	R	R	R
Silt	C	C	R
Clay	D	D	D
Composition:			
Quartz	–	T	–
Mica	T	–	–
Heavy minerals	–	T	T
Clay	T	T	–
Volcanic glass	T	T	T
Pyrite	T	R	R
Carbonate unspec.	–	T	–
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 591 HOLE CORE 10 CORED INTERVAL 80.2–89.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. tosaensis
NN16
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
P
5Y 8/1
5Y 8/1
P
5P 4/2
5Y 8/1
5P 4/1
IW
5Y 8/1
5Y 8/1
5Y 8/1
5P 4/1
5P 4/1
P
P

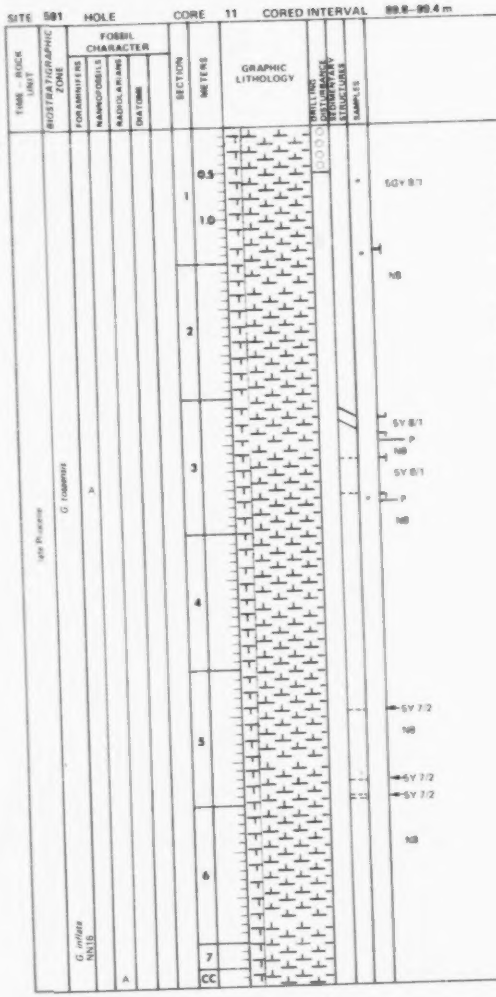
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light greenish gray (5GY 8/1) to light grayish green (5G 8/1), soft, with swirls, streaks, and halos of various shades of grayish purple (5P 4/2) of iron sulfide. *Planolites* burrows are only identifiable burrows but mottles are common.

SMEAR SLIDE SUMMARY:

	2, 35	3, 70
	D	D
Composition:		
Quartz	T	T
Feldspar	–	T
Volcanic glass	R	T
Pyrite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	T	–

SITE 591 HOLE CORE 11 CORED INTERVAL 89.8–99.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. tosaensis
G. inflata
NN16
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/1
N8
5Y 8/1
P
N8
5Y 8/1
P
N8
5Y 7/2
N8
5Y 7/2
5Y 7/2
N8

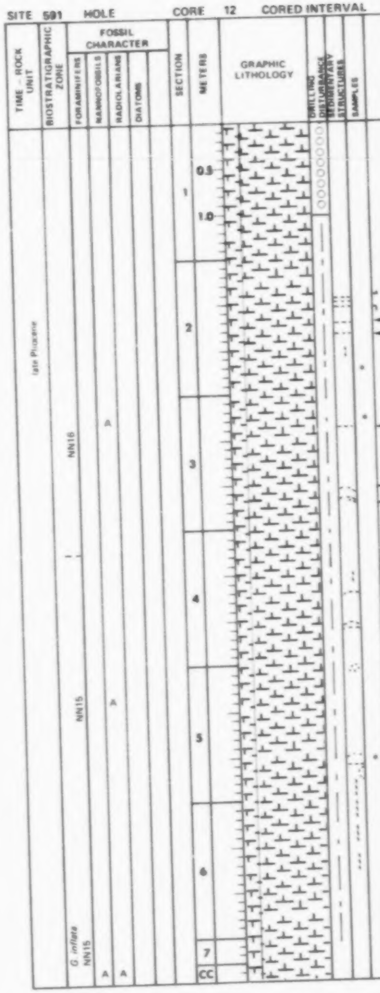
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light greenish gray (5GY 8/1) grading to very light gray (N8). Soft and homogeneous with streaks of grayish purple (5P 4/2) iron sulfide throughout. Iron sulfide bands become horizontal by Section 3. Mottles of yellowish gray (5Y 7/2) and thin laminae (<2 mm) are common. A few *Planolites* occur.

SMEAR SLIDE SUMMARY:

	1, 75	1, 145	3, 107
	D	D	D
Composition:			
Quartz	–	T	–
Feldspar	T	T	T
Heavy minerals	T	–	T
Volcanic glass	T	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 591 HOLE CORE 12 CORED INTERVAL 99.4–109.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN16
NN15
G. inflata
NN15
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 7/2
5GY 7/2
5GY 7/2
P
5GY 7/2
5GY 7/2
5GY 7/2
P
P
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
N7

LITHOLOGIC DESCRIPTION

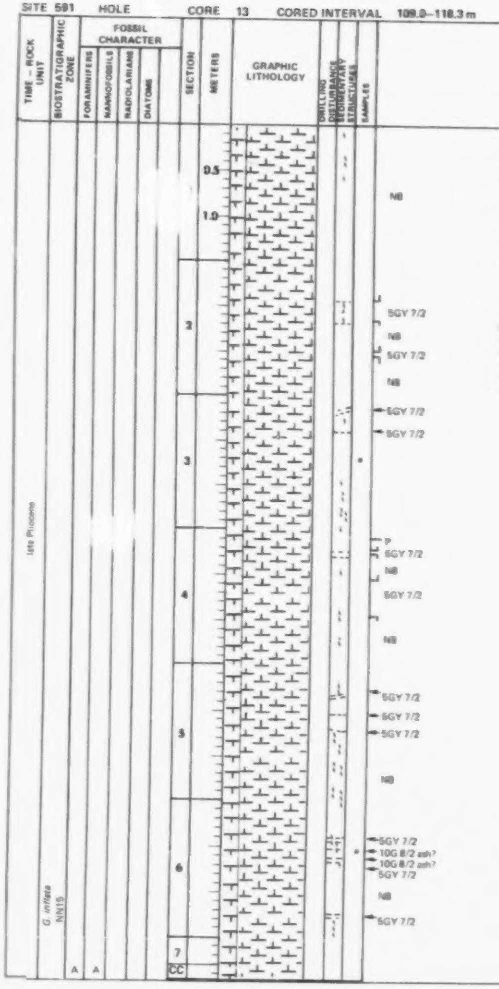
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Faint mottles of grayish yellow green occur scattered throughout. Streaks of iron sulfide become bands <2 mm thick and horizontal by Section 3.

Interbeds, and mottles of dark yellowish green (5GY 7/2) contains possible volcanic glass.

SMEAR SLIDE SUMMARY:

	2, 100	3, 36	5, 105
	D	D	D
Composition:			
Quartz	T	–	–
Feldspar	T	–	T
Heavy minerals	–	T	T
Volcanic glass	T	T	T
Pyrite	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	T	T	T
Sponge spicules	–	T	T

SITE 591 HOLE CORE 13 CORED INTERVAL 109.0–118.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN15
A
A
0.5
1.0
2
3
4
5
6
7
CC
NB
5GY 7/2
NB
5GY 7/2
NB
5GY 7/2
5GY 7/2
P
5GY 7/2
NB
5GY 7/2
NB
5GY 7/2
5GY 7/2
5GY 7/2
NB
5GY 7/2
10G 8/2 ash?
10G 8/2 ash?
5GY 7/2
NB
5GY 7/2

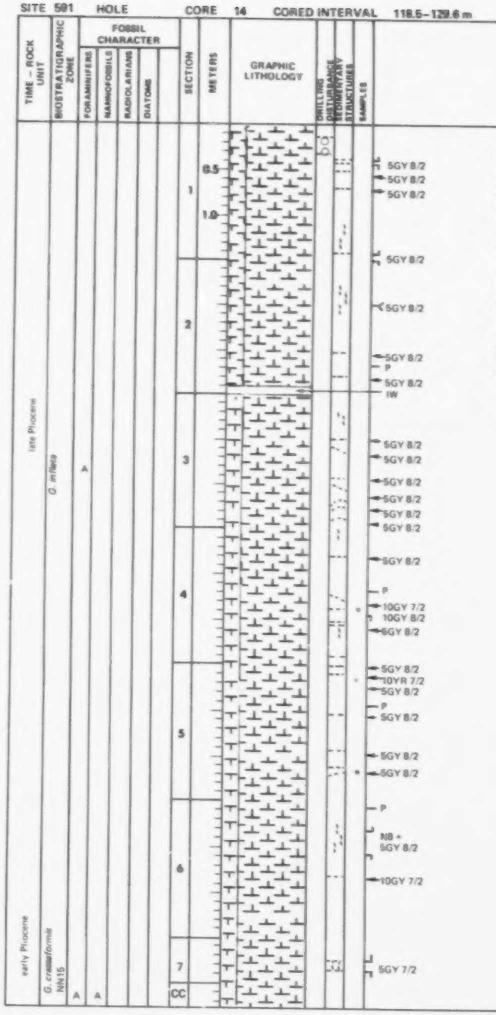
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft to stiff. Common blebs, streaks, and thin laminae (<2 mm) of iron sulfide. Burrow mottles of grayish yellow green (5GY 7/2) and interbeds of same color occur scattered throughout. Burrow mottles become more apparent with depth. Possible ash layers (< 1 mm thick) occur at Section 6, 58 and 62 cm.

SMEAR SLIDE SUMMARY:

	3, 70	6, 51
	D	D
Composition:		
Feldspar	–	T
Mica	T	T
Heavy minerals	T	T
Volcanic glass	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	T	T

SITE 591 HOLE CORE 14 CORED INTERVAL 118.5–129.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
early Pliocene
G. crassaformis
NN15
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
P
5GY 8/2
IW
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
5GY 8/2
P
10GY 7/2
10GY 8/2
5GY 8/2
5GY 8/2
10YR 7/2
5GY 8/2
P
5GY 8/2
5GY 8/2
5GY 8/2
P
N8 +
5GY 8/2
10GY 7/2
5GY 7/2

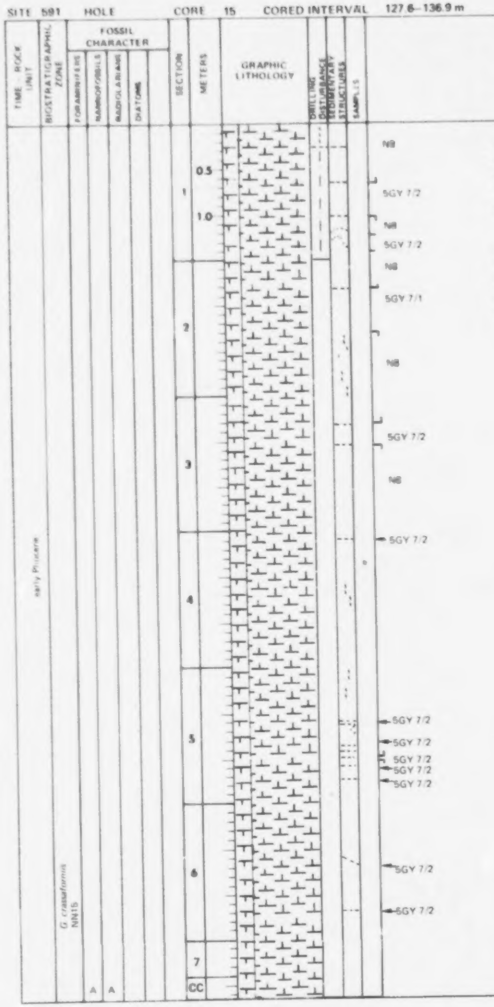
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, with streaks and laminae (< 2 mm) of iron sulfide. Laminae and interbeds of light grayish yellow green (5GY 8/2) occur throughout. Burrow mottles are conspicuous and a few planolites occur. A few pale yellowish green (10GY 7/2) laminae.

SMEAR SLIDE SUMMARY:

	4, 82	5, 19	5, 108
	D	D	M
Composition:			
Quartz	–	T	–
Feldspar	T	T	T
Heavy minerals	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Radiolarians	–	T	–
Sponge spicules	T	T	T

SITE 591 HOLE CORE 15 CORED INTERVAL 127.6–136.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 7/2
N8
5GY 7/2
N8
5GY 7/1
N8
5GY 7/2
N8
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2

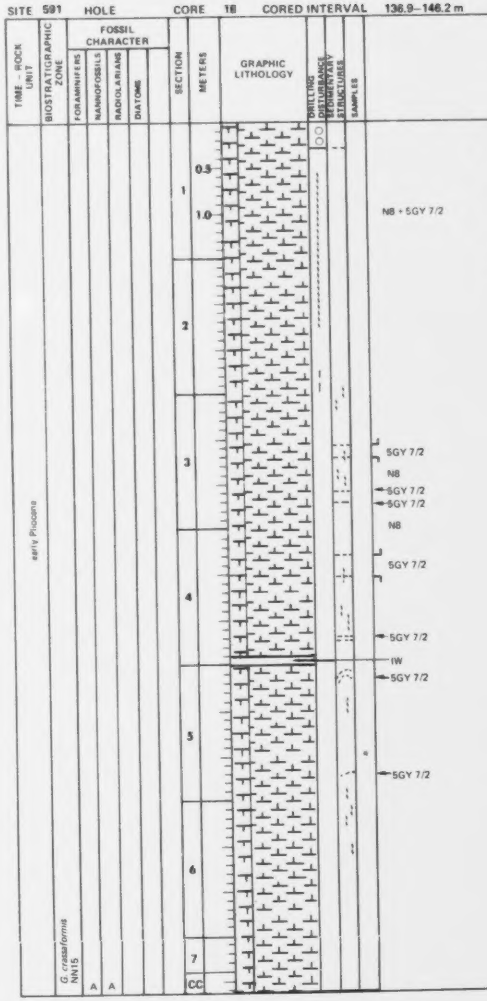
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with interbeds and burrow mottles of grayish yellow green (5GY 7/2), soft, with streaks and blebs of iron sulfide scattered throughout.

SMEAR SLIDE SUMMARY:

	4, 38 D
Composition:	
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE CORE 16 CORED INTERVAL 136.9–146.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8 + 5GY 7/2
5GY 7/2
N8
5GY 7/2
5GY 7/2
N8
5GY 7/2
5GY 7/2
IW
5GY 7/2
5GY 7/2

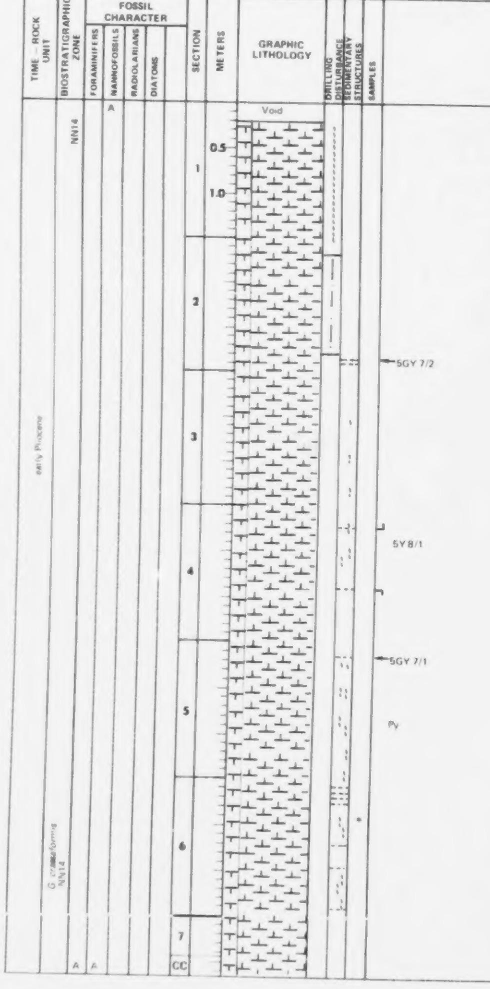
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with mottles of grayish yellow green (5GY 7/2) and interbeds of same. Specks, streaks, and a few burrow outlines of medium light gray (N4) scattered throughout. Sections 1 and 2 badly disturbed by coring.

SMEAR SLIDE SUMMARY:

	5, 92 D
Composition:	
Heavy minerals	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 591 HOLE CORE 17 CORED INTERVAL 146.2–155.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN14
G. crassaformis
NN14
A
A
A
Void
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 7/2
5Y 8/1
5GY 7/1
Py

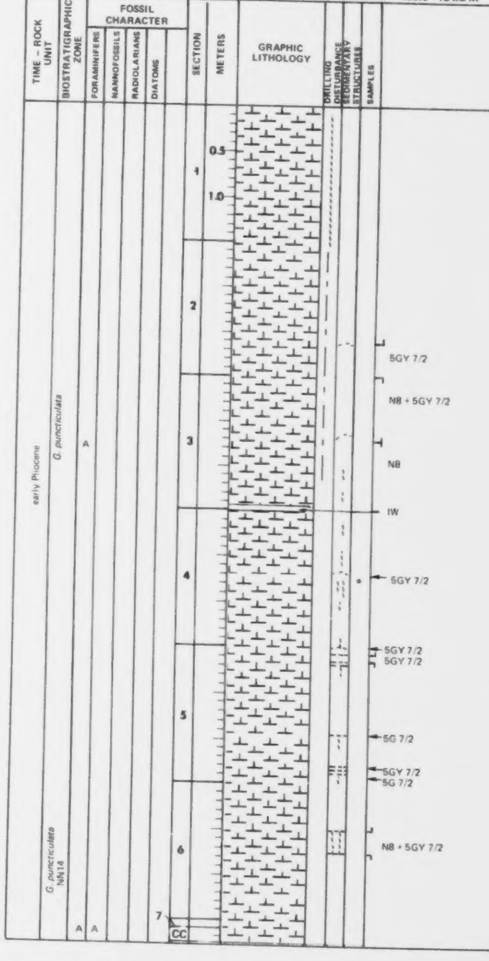
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with mottles and zones of grayish yellow green (5GY 7/2). Iron sulfide streaks, medium dark gray (N4) common. H_2S odor released when split. Yellowish gray interbed at Section 4, 25–83 cm.

SMEAR SLIDE SUMMARY

	6, 43
	D
Composition:	
Feldspar	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 591 HOLE CORE 18 CORED INTERVAL 155.5–164.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
G. puncticulata
NN14
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 7/2
N8 + 5GY 7/2
N8
IW
5GY 7/2
5GY 7/2
5GY 7/2
5G 7/2
5GY 7/2
5G 7/2
N8 + 5GY 7/2

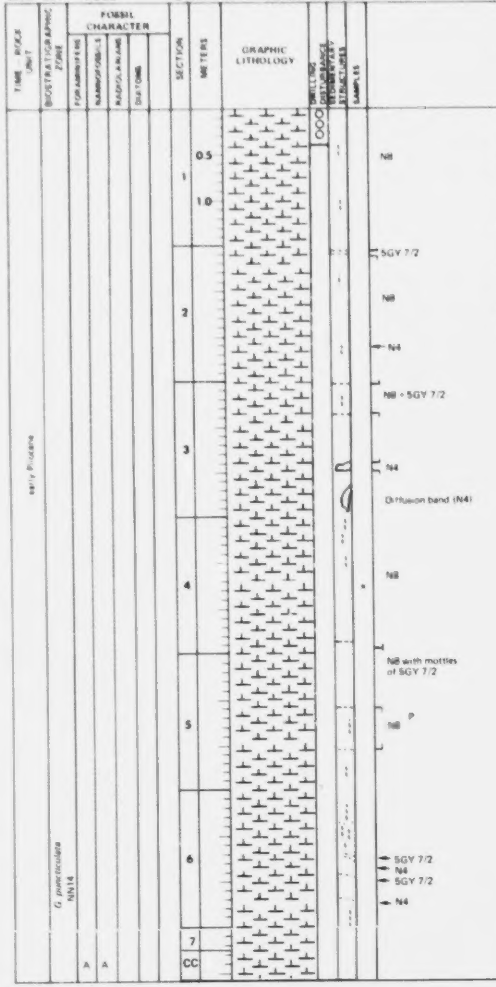
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, with streaks and laminae of medium dark gray (N4) iron sulfide throughout. Mottles and thin (<2 mm) laminae of grayish yellow green (5GY 7/2) common. Two thin (<1 mm) very subtle pale green (5G 7/2) laminae occur in Section 5.

SMEAR SLIDE SUMMARY:

	4, 74
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE CORE 19 CORED INTERVAL 164.8–174.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN14
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5GY 7/2
N8
N4
N8 + 5GY 7/2
N4
Diffusion band (N4)
N8
N8 with mottles of 5GY 7/2
N8
P
5GY 7/2
N4
5GY 7/2
N4

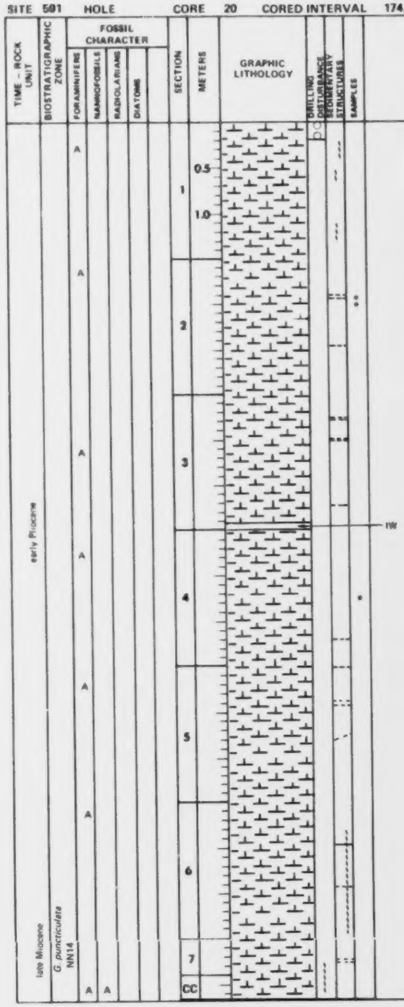
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, with streaks and thin laminae of medium dark gray (N4) iron sulfides common throughout. Mottles and zones of grayish yellow green (5GY 7/2) scattered throughout. Dark volcanic glass in insoluble residue at Section 5, 147 cm.

SMEAR SLIDE SUMMARY

	4, 72
	D
Composition	
Feldspar	T
Foraminifers	T
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE CORE 20 CORED INTERVAL 174.3–183.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
G. puncticulata
NN14
A
A
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
IW

LITHOLOGIC DESCRIPTION

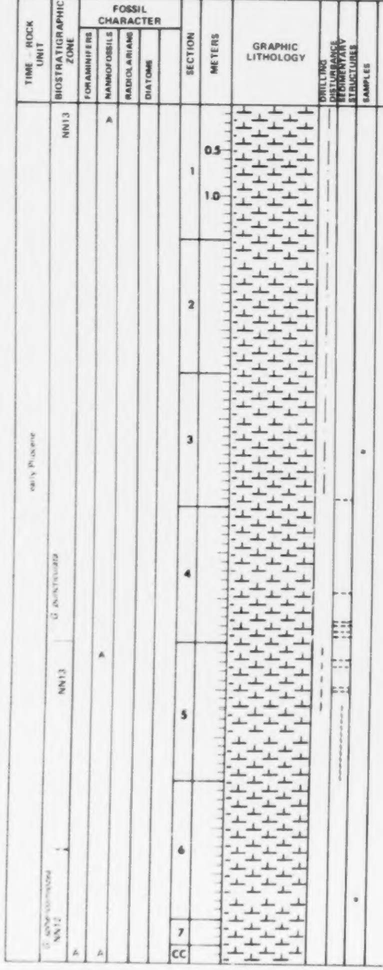
NANNOFOSSIL OOZE, very light gray (N8), soft, with streaks, spots, and thin laminae of light gray (N7) iron sulfides common throughout. Burrow mottles of light greenish gray (5GY 8/1) scattered throughout.

Double-color (laminae) bands of light greenish gray (5G 8/1) and light gray (N7) occur.

SMEAR SLIDE SUMMARY:

	2, 53	2, 54	4, 76
	M	M	D
Texture:			
Sand	T	T	T
Silt	T	T	T
Clay	D	D	D
Composition:			
Quartz	T	T	–
Mica	T	T	T
Heavy minerals	T	T	–
Volcanic glass	T	T	T
Pyrite	–	R	T
Carbonate unspec.	T	–	–
Foraminifers	R	T	R
Calc. nannofossils	D	D	D
Radiolarians	–	–	T
Sponge spicules	–	–	T

SITE 591 HOLE CORE 21 CORED INTERVAL 183.8–193.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN13
G. puncticulata
NN13
G. sphericomiozea
NN12
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

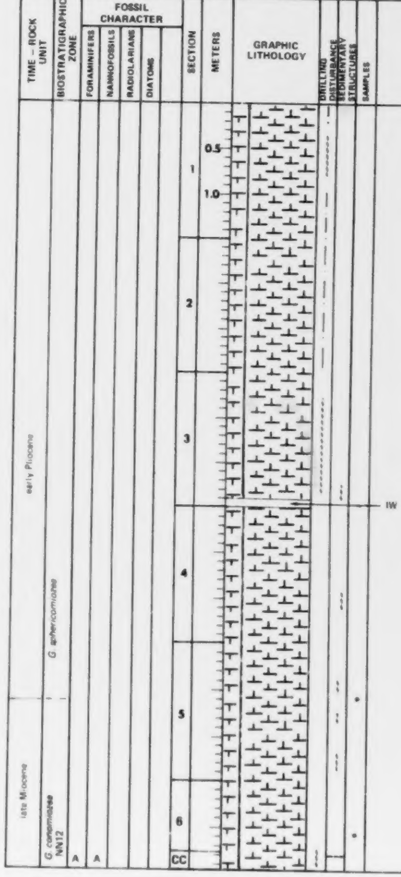
NANNOFOSSIL OOZE, very light gray (N8), soft, slightly to moderately deformed by drilling.

Light greenish gray (5GY 8/1) and light gray (N7) mottles scattered.

SMEAR SLIDE SUMMARY

	3, 80	6, 125
	D	D
Texture:		
Sand	T	R
Silt	T	R
Clay	D	D
Composition		
Quartz	T	T
Mica	–	T
Heavy minerals	T	T
Volcanic glass	–	T
Pyrite	T	–
Carbonate unspec.	–	T
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	–	T
Radiolarians	T	–
Sponge spicules	–	T
Silicoflagellates	T	T

SITE 591 HOLE CORE 22 CORED INTERVAL 193.3–202.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
G. sphericomiozea
G. conomiozea
NN12
A
A
0.5
1.0
1
2
3
4
5
6
CC
IW

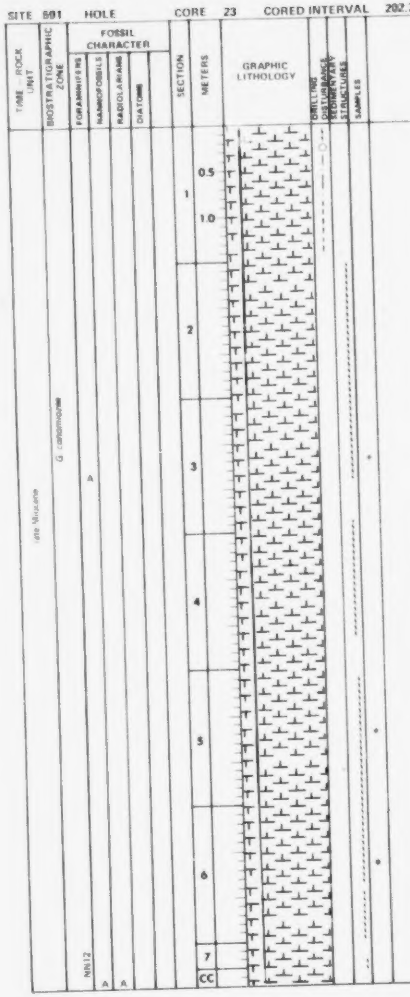
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft; very light gray (N8), upper half; light greenish gray (5GY 8/1), lower; with mottles of yellowish gray (5Y 8/1) and light gray (N6–N7).

SMEAR SLIDE SUMMARY:

	5, 60	6, 55
	D	D
Composition:		
Quartz	–	T
Feldspar	T	–
Mica	T	T
Heavy minerals	T	T
Volcanic glass	–	T
Pyrite	T	T
Foraminifers	C	C
Calc. nannofossils	D	D
Diatoms	T	–
Radiolarians	–	T
Sponge spicules	T	T

SITE 591 HOLE CORE 23 CORED INTERVAL 202.7–212.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN12
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, with burrow mottles of light gray (N6–N7) and yellowish gray (5GY 8/1–5GY 7/2)

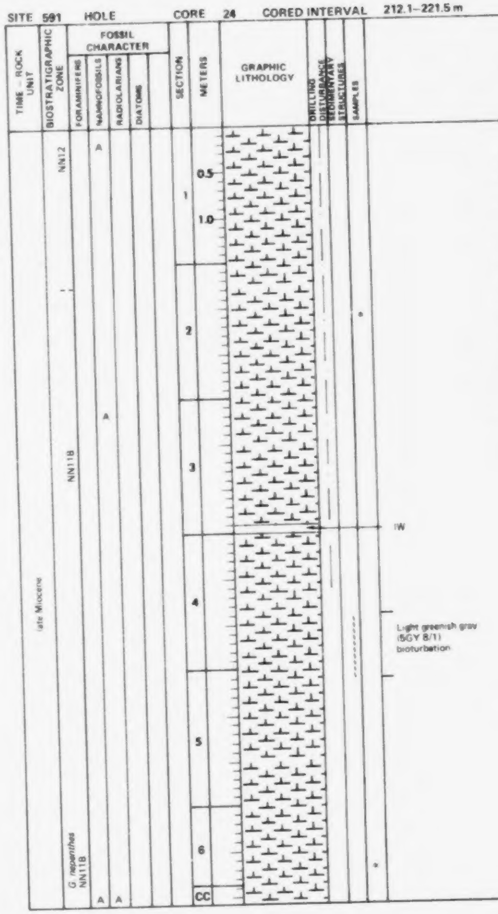
Accessory pyrite of medium gray (N4)

Moderately bioturbed

SMEAR SLIDE SUMMARY

	3, 65	5, 66	6, 60
	D	M	D
Texture			
Sand	T	T	T
Silt	R	R	R
Clay	D	D	D
Composition			
Quartz	T	T	T
Feldspar	–	T	T
Mica	–	–	T
Heavy minerals	T	T	T
Pyrite	T	T	–
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Diatoms	T	–	T
Radiolarians	–	T	–
Sponge spicules	T	T	–

SITE 591 HOLE CORE 24 CORED INTERVAL 212.1–221.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN12
NN11B
G. nepenthes
NN11B
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
IW
Light greenish gray (5GY 8/1) bioturbation

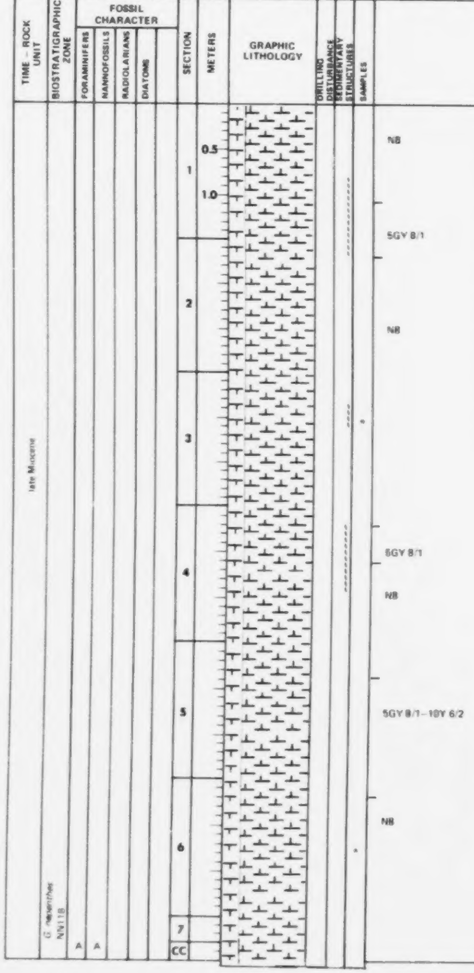
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, with mottles of pale olive (10Y 6/2) and light gray (N7) in color

SMEAR SLIDE SUMMARY:

	2, 70	6, 60
	D	D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Quartz	T	T
Feldspar	–	T
Mica	T	T
Heavy minerals	T	–
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	T	T
Sponge spicules	–	T

SITE 591 HOLE CORE 25 CORED INTERVAL 221.5–231.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1–10Y 6/2
N8

LITHOLOGIC DESCRIPTION

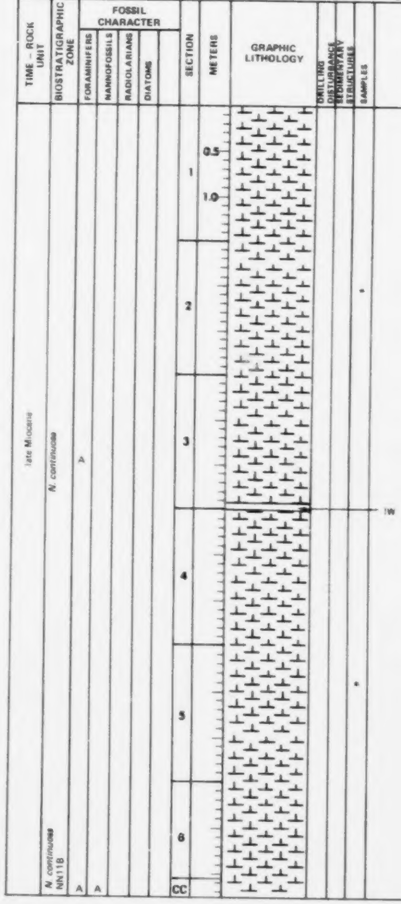
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light greenish gray (5GY 8/1), soft, with burrow mottles of yellowish gray (5Y 7/2) and medium to light gray (N5 to N7), and with iron sulfides of dark gray (N4).

Mixed by bioturbation.

SMEAR SLIDE SUMMARY

	3, 80	6, 80
	D	D
Texture:		
Sand	R	T
Silt	R	R
Clay	D	D
Composition:		
Quartz	T	T
Mica	T	T
Heavy minerals	–	T
Volcanic glass	T	–
Pyrite	T	T
Carbonate unspec.	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Radiolarians	T	–

SITE 591 HOLE CORE 26 CORED INTERVAL 231.1–240.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
A
N. continuosa
NN11B
A
A
1
2
3
4
5
6
CC
0.5
1.0
IW

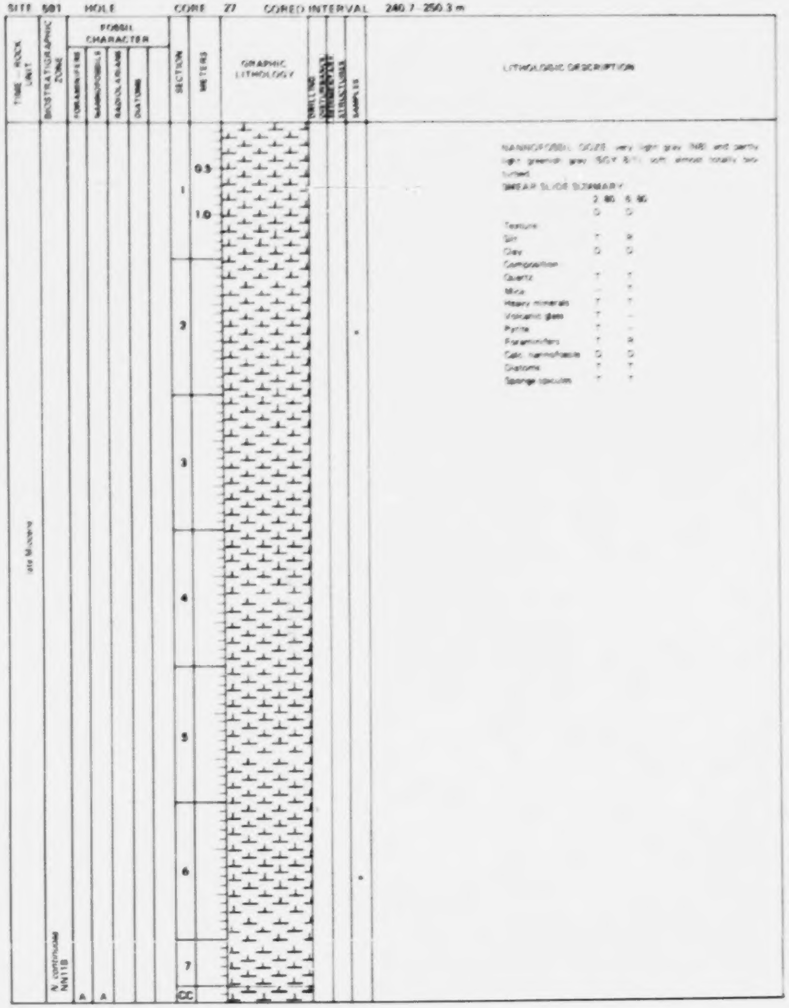
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, with mottles of grayish yellow green (5GY 7/2); almost totally bioturbated.

SMEAR SLIDE SUMMARY:

	2, 95	5, 40
	D	D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Quartz	T	–
Feldspar	T	T
Heavy minerals	T	T
Pyrite	T	–
Carbonate unspec.	–	T
Foraminifers	R	T
Calc. nannofossils	D	D
Diatoms	–	T
Radiolarians	T	–
Sponge spicules	T	–

SITE 591 HOLE CORE 27 CORED INTERVAL 240.7–250.3 m

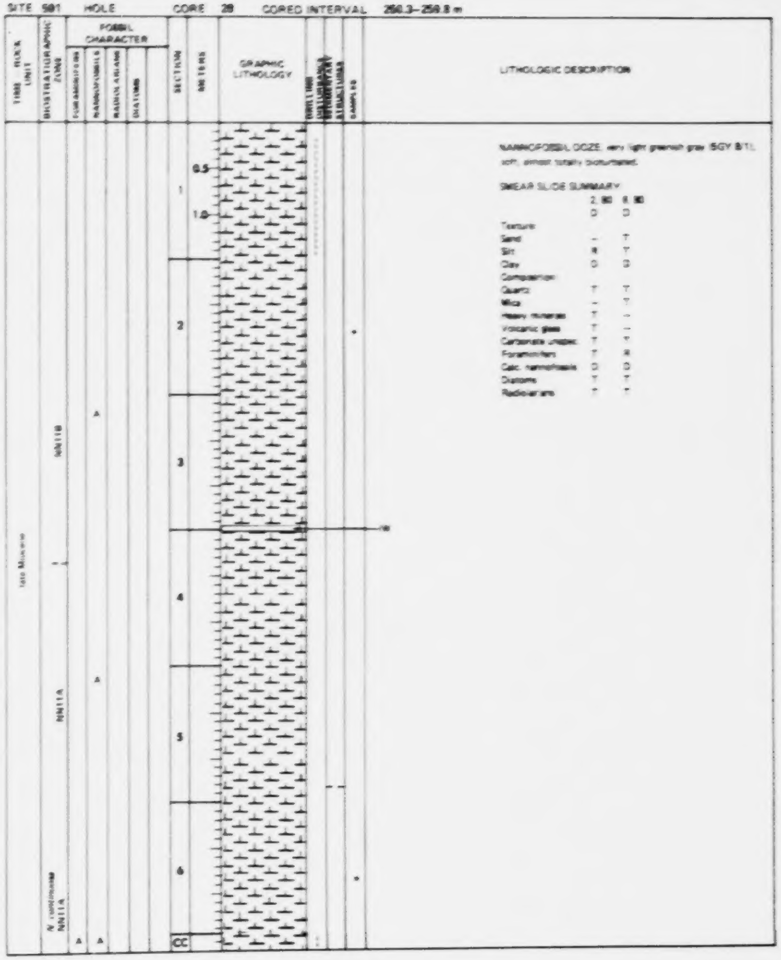

TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N. continuosa
NN11B
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

NANNOFOSSIL OOZE, very light gray (N8) and partly light greenish gray (5GY 8/1), soft, almost totally bioturbed.

SMEAR SLIDE SUMMARY

	2, 80	6, 80
	D	D
Texture		
Silt	T	R
Clay	D	D
Composition		
Quartz	T	T
Mica	—	T
Heavy minerals	T	T
Volcanic glass	T	—
Pyrite	T	—
Foraminifers	T	R
Calc. nannofossils	D	D
Diatoms	T	T
Sponge spicules	T	T

SITE 591 HOLE CORE 28 CORED INTERVAL 250.3–259.8 m

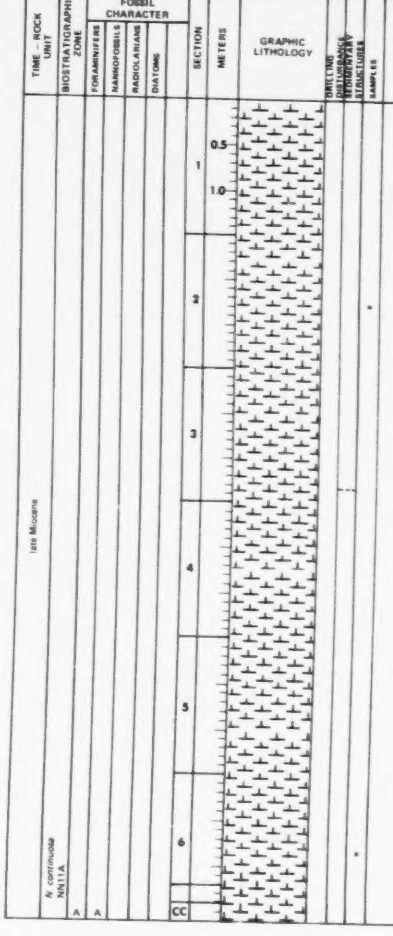

TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN11B
NN11A
N. continuosa
NN11A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC

NANNOFOSSIL OOZE, very light greenish gray (5GY 8/1), soft, almost totally bioturbated.

SMEAR SLIDE SUMMARY

	2, 80	6, 80
	D	D
Texture		
Sand	—	T
Silt	R	T
Clay	D	D
Composition		
Quartz	T	T
Mica	—	T
Heavy minerals	T	—
Volcanic glass	T	—
Carbonate unspec.	T	T
Foraminifers	T	R
Calc. nannofossils	D	D
Diatoms	T	T
Radiolarians	T	T

SITE 591 HOLE CORE 29 CORED INTERVAL 259.8–269.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
0.5
1.0
1
2
3
4
5
6
CC

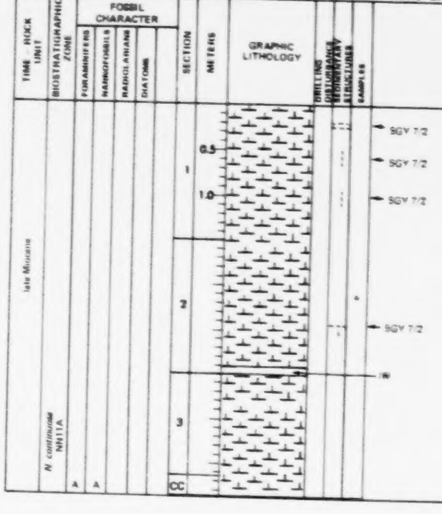
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, almost totally bioturbated, with burrow mottles (rim of light gray [N7] and core of grayish yellow green [5GY 7/2]).

SMEAR SLIDE SUMMARY

	2, 80	6, 80
	D	D
Texture		
Sand	T	T
Silt	T	R
Clay	D	D
Composition		
Quartz	T	–
Mica	T	T
Heavy minerals	–	T
Carbonate unspec	–	T
Foraminifers	T	R
Calc. nannofossils	D	D
Diatoms	T	–
Radiolarians	T	T
Sponge spicules	T	T

SITE 591 HOLE CORE 30 CORED INTERVAL 269.3–274.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
0.5
1.0
1
2
3
CC
5GY 7/2
5GY 7/2
5GY 7/2
5GY 7/2
IW

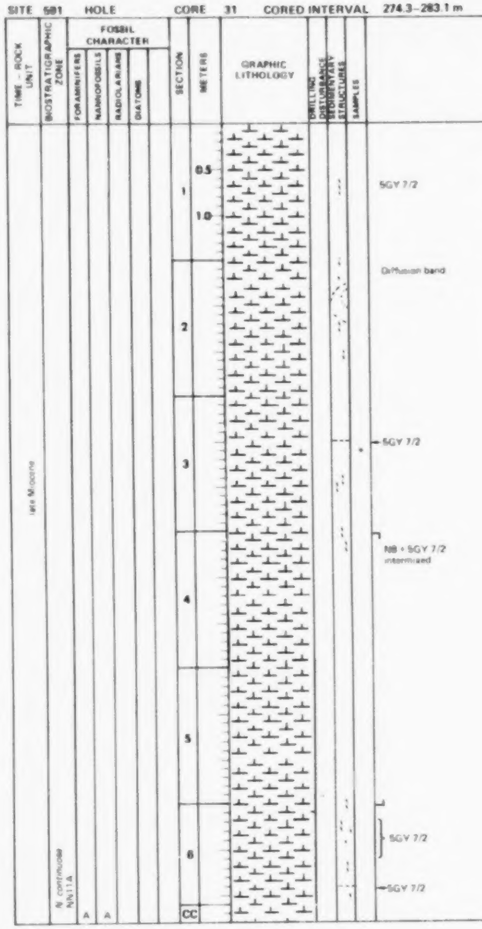
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), stiff, with mottles and faint interbeds of grayish yellow green (5GY 7/2). Streaks of medium dark gray (N4) iron sulfide.

SMEAR SLIDE SUMMARY

	2, 83
	D
Composition:	
Foraminifers	R
Calc. nannofossils	D
Diatoms	R
Sponge spicules	T

SITE 591 HOLE CORE 31 CORED INTERVAL 274.3–283.1 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
0.5
1.0
1
2
3
4
5
6
CC
5GY 7/2
Diffusion band
5GY 7/2
N8 + 5GY 7/2 intermixed
5GY 7/2
5GY 7/2

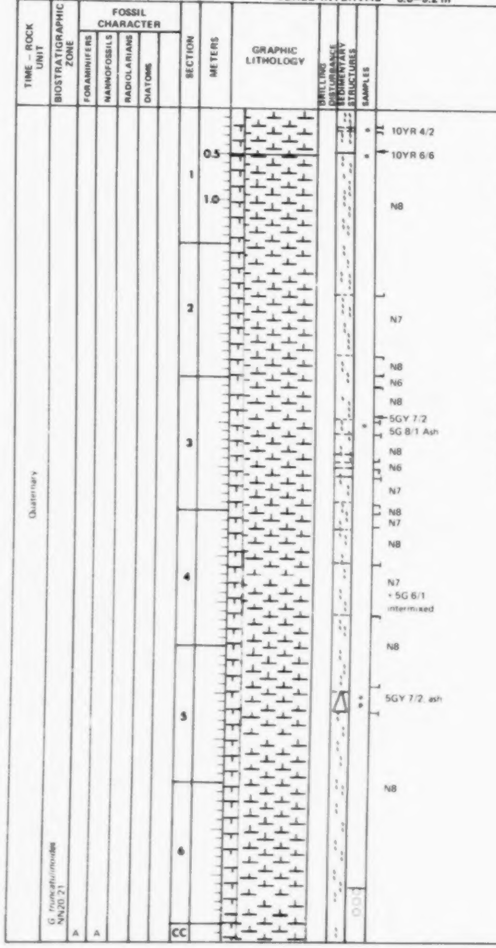
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, with streaks of medium dark gray (N4) iron sulfide common throughout. Faint mottles of grayish yellow green (5GY 7/2) rare to common.

SMEAR SLIDE SUMMARY

	3, 71 D
Composition	
Quartz	T
Feldspar	T
Palagonite	T
Foraminifers	T
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE A CORE 1 CORED INTERVAL 0.0–9.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN20 21
A
A
0.5
1.0
1
2
3
4
5
6
CC
10YR 4/2
10YR 6/6
N8
N7
N8
N6
N8
5GY 7/2
5G 8/1 Ash
N8
N6
N7
N8
N7
N8
N7
+ 5G 6/1
intermixed
N8
5GY 7/2, ash
N8

LITHOLOGIC DESCRIPTION

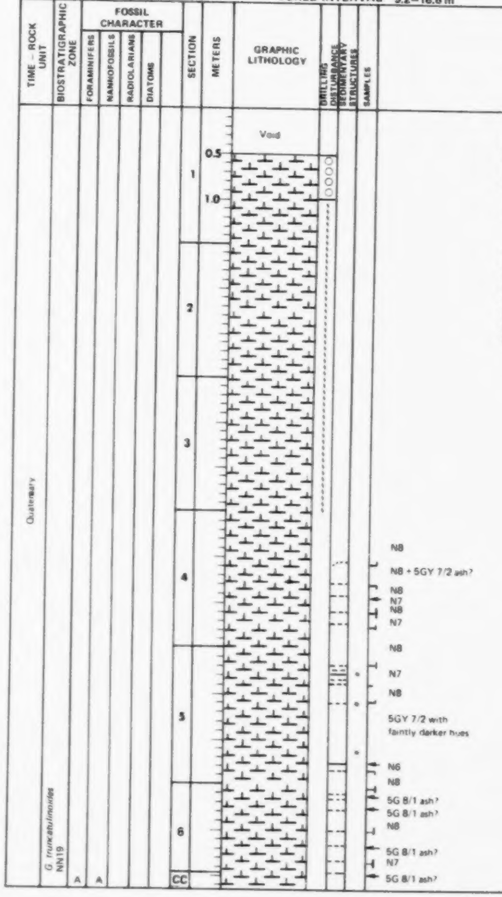
FORAMINIFER-BEARING NANNOFOSSIL OOZE, pale yellowish brown (10YR 6/4), soft, intensely bioturbated, with bioturbated interbed of dark yellowish brown (10YR 4/2). Sequence has various faint hues of yellow browns (10YR). Contact with underlying FORAMINIFER-BEARING NANNOFOSSIL OOZE is sharp with a distinct band (2 mm thick) of dark yellowish orange (10YR 6/6).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N7) and very light gray (N8) color cycles, soft, intensely bioturbated. Streaks of dark gray (N3) iron sulfides common throughout. A few mottles of grayish yellow green (5GY 7/2) occur. Color cycles become medium light gray (N6) in Section 3. Fining upward interbed occurs in Section 5 with coarse-grained, ash-rich base.

SMEAR SLIDE SUMMARY:

	1, 29	3, 61	4, 48	5, 60	5, 69
	M	D	D	M	M
Composition:					
Quartz	–	–	–	–	T
Feldspar	T	T	T	T	T
Heavy minerals	T	–	–	T	–
Volcanic glass	–	C	–	C	A
Foraminifers	C	C	R	C	–
Calc. nannofossils	A	A	A	A	–
Sponge spicules	T	–	–	–	–

SITE 591 HOLE A CORE 2 CORED INTERVAL 9.2–18.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
0.5
1.0
1
2
3
4
5
6
CC
Void
N8
N8 + 5GY 7/2 ash?
N8
N7
N8
N7
N8
N7
N8
5GY 7/2 with
faintly darker hues
N6
N8
5G 8/1 ash?
5G 8/1 ash?
N8
5G 8/1 ash?
N7
5G 8/1 ash?

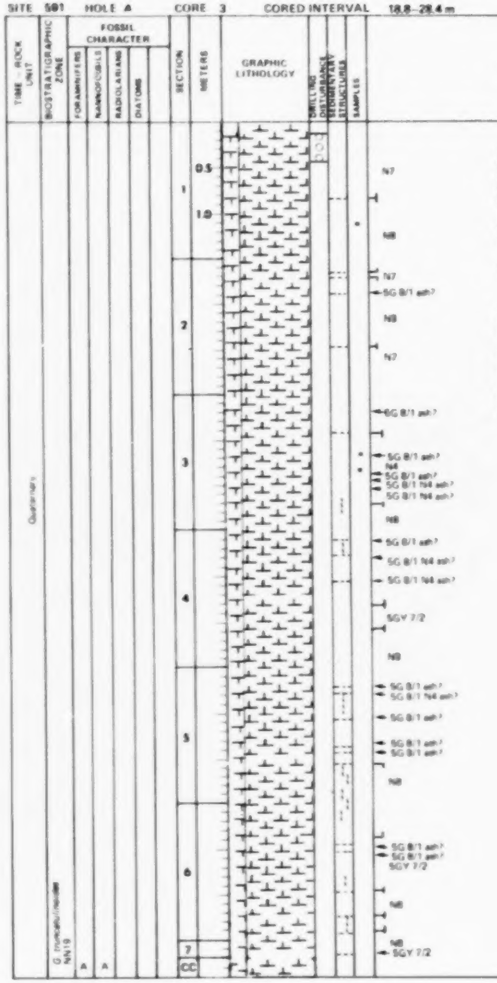
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, alternations of very light gray (N8) and light gray (N7), soft, streaks of medium dark gray (N4) iron sulfides throughout. Several thin zones of ash(?), light greenish gray (5G 8/1). Several zones of grayish yellow green (5GY 7/2) with mottles.

SMEAR SLIDE SUMMARY:

	5, 37	5, 67	5, 118	6, 22
	D	M	M	M
Composition:				
Quartz	–	T	–	–
Feldspar	T	T	–	–
Heavy minerals	–	–	T	–
Volcanic glass	–	–	T	–
Pyrite	–	–	T	C
Foraminifers	R	C	C	D
Calc. nannofossils	D	D	D	C

SITE 591 HOLE A CORE 3 CORED INTERVAL 18.8–28.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N8
N7
SG 8/1 ash?
N8
N7
SG 8/1 ash?
SG 8/1 ash?
N4
SG 8/1 ash?
SG 8/1 N4 ash?
SG 8/1 N4 ash?
N8
SG 8/1 ash?
SG 8/1 N4 ash?
SG 8/1 N4 ash?
5GY 7/2
N8
SG 8/1 ash?
SG 8/1 N4 ash?
SG 8/1 ash?
SG 8/1 ash?
SG 8/1 ash?
N8
SG 8/1 ash?
SG 8/1 ash?
5GY 7/2
N8
N8
5GY 7/2

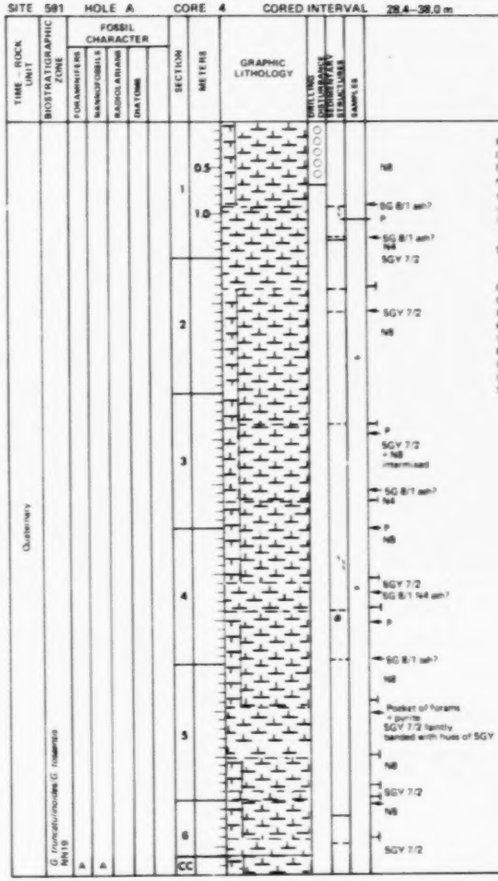
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE cycles of light gray (N7) and very light gray (N8) with very faint hues of (5G) throughout. Medium dark gray (N4) iron sulfide streaks and laminae common. Mottles common. Doublets of light greenish gray (5Y 8/1) above a band of (N4) very common from Section 3 down. Pockets of forams, pyrite, cemented by anhydrite(?) occur in Sections 3, 4, and 5.

SMEAR SLIDE SUMMARY

	1, 124	3, 67	3, 86
	D	M	M
Composition:			
Quartz	T	T	–
Feldspar	R	T	T
Heavy minerals	–	–	T
Volcanic glass	–	T	T
Palagonite	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Sponge spicules	–	T	–

SITE 591 HOLE A CORE 4 CORED INTERVAL 28.4–38.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
SG 8/1 ash?
P
SG 8/1 ash?
N4
5GY 7/2
5GY 7/2
N8
P
5GY 7/2
+ N8
intermixed
SG 8/1 ash?
N4
P
N8
5GY 7/2
SG 8/1 N4 ash?
P
SG 8/1 ash?
N8
Pocket of forams
+ pyrite
5GY 7/2 faintly
banded with hues of 5GY
N8
5GY 7/2
N8
5GY 7/2

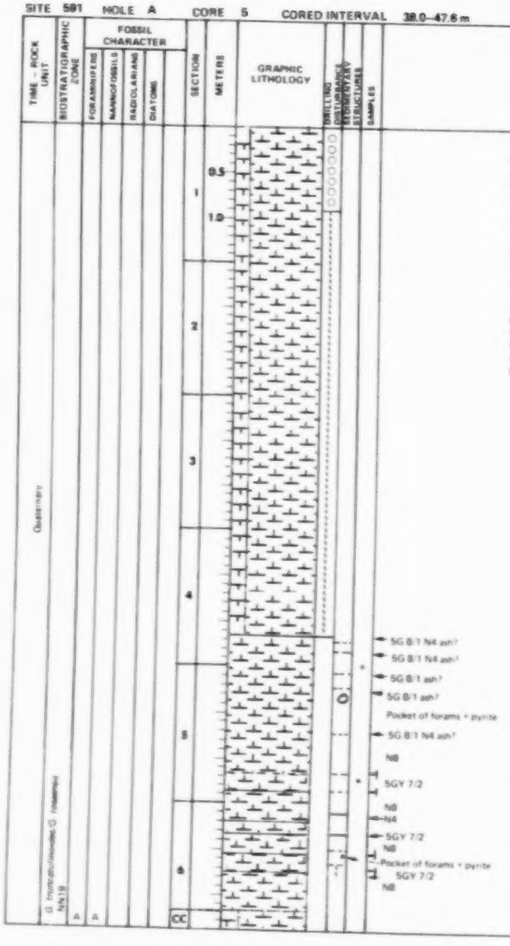
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (5GY 7/2) alternating with NANNOFOSSIL OOZE, grayish yellow green (N8), soft, homogeneous, mottled, common medium dark gray (N4) streaks of iron sulfide. Doublets of pale greenish gray (5G 8/1) and medium dark gray (N4) may be altered ash. Small pockets of forams, pyrite and aragonite(?) occur in Section 5.

SMEAR SLIDE SUMMARY

	2, 118	4, 78
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Heavy minerals	–	T
Volcanic glass	–	T
Pyrite	–	T
Foraminifers	C	R
Calc. nannofossils	D	D
Sponge spicules	T	–

SITE 591 HOLE A CORE 5 CORED INTERVAL 38.0–47.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19
A
A
0.5
1.0
1
2
3
4
5
6
CC
5G 8/1 N4 ash?
5G 8/1 N4 ash?
5G 8/1 ash?
5G 8/1 ash?
Pocket of forams + pyrite
5G 8/1 N4 ash?
N8
5GY 7/2
N8
N4
5GY 7/2
N8
Pocket of forams + pyrite
5GY 7/2
N8

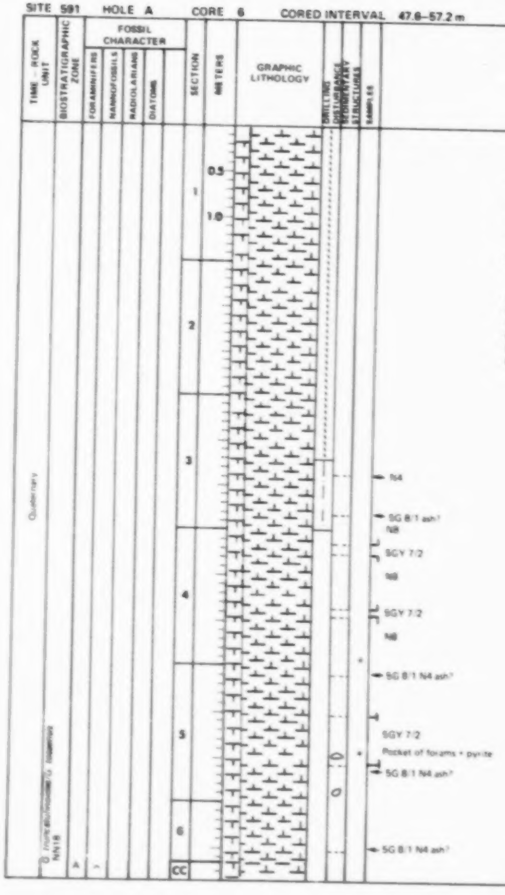
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8) alternating with FORAMINIFER-BEARING NANNOFOSSIL OOZE, grayish yellow green (5GY 7/2), soft, mottled, common streaks of iron sulfide of medium dark gray (N4) and several doublets of altered ash(?) of light greenish gray (5G 8/1) and medium dark gray (N4). Two pockets of forams and pyrite at Section 5, 32 cm and Section 6, 57 and 66 cm. Chemical diffusion bands common.

SMEAR SLIDE SUMMARY

	5, 7	5, 122
	D	D
Composition:		
Feldspar	—	T
Volcanic glass	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 591 HOLE A CORE 6 CORED INTERVAL 47.6–57.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN18
A
0.5
1.0
1
2
3
4
5
6
CC
N4
5G 8/1 ash?
N8
5GY 7/2
N8
5GY 7/2
N8
5G 8/1 N4 ash?
5GY 7/2
Pocket of forams + pyrite
5G 8/1 N4 ash?
5G 8/1 N4 ash?

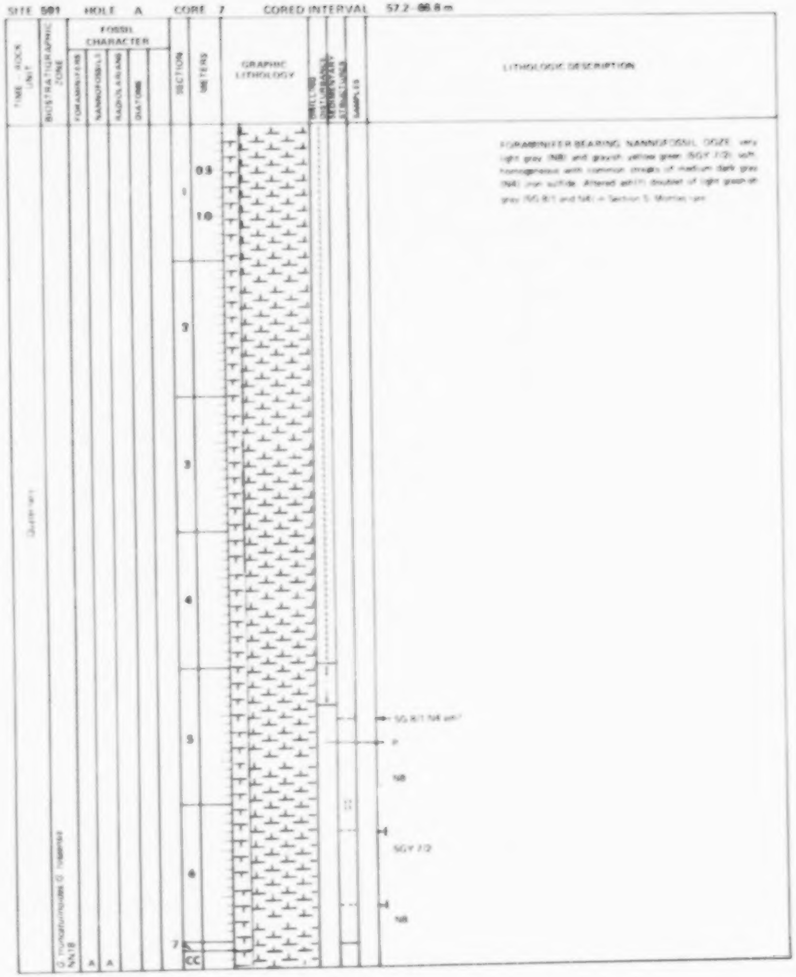
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, alternating very light gray (N8) and grayish yellow green (5GY 7/2), soft, with streaks of medium dark gray (N4) iron sulfide, and doublets of altered ash(?) light greenish gray (5G 8/1) and (N4). Pockets of forams and pyrite in Sections 5 and 6.

SMEAR SLIDE SUMMARY

	4, 13	5, 96
	D	D
Composition:		
Feldspar	T	T
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

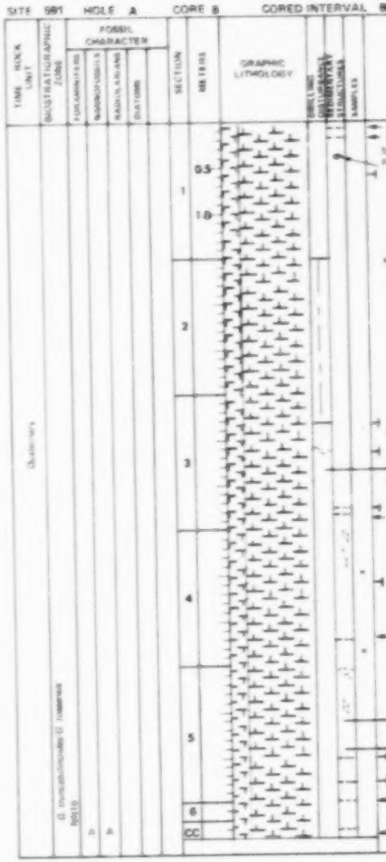
SITE 591 HOLE A CORE 7 CORED INTERVAL 57.2–66.8 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN18
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
5G 8/1 N4 ash?
P
N8
5GY 7/2
N8

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) and grayish yellow green (5GY 7/2), soft, homogeneous with common streaks of medium dark gray (N4) iron sulfide. Altered ash(?) doublet of light greenish gray (5G 8/1 and N4) in Section 5. Mottles rare.

SITE 591 HOLE A CORE 8 CORED INTERVAL 66.8–76.4 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides/G. tosaensis
NN19
A
A
1
2
3
4
5
6
CC
0.5
1.0

N4
N4
5GY 7/2
Pocket of forams + pyrite
N8
5GY 7/2 + N4
N8
Chemical diffusion bands
5G 8/1 N4 ash?
N8
5GY 6/2
5G 8/1 N4 ash?
N8
P
P
5GY 7/2
N8
5GY 7/2
5G 8/1 N4 ash?

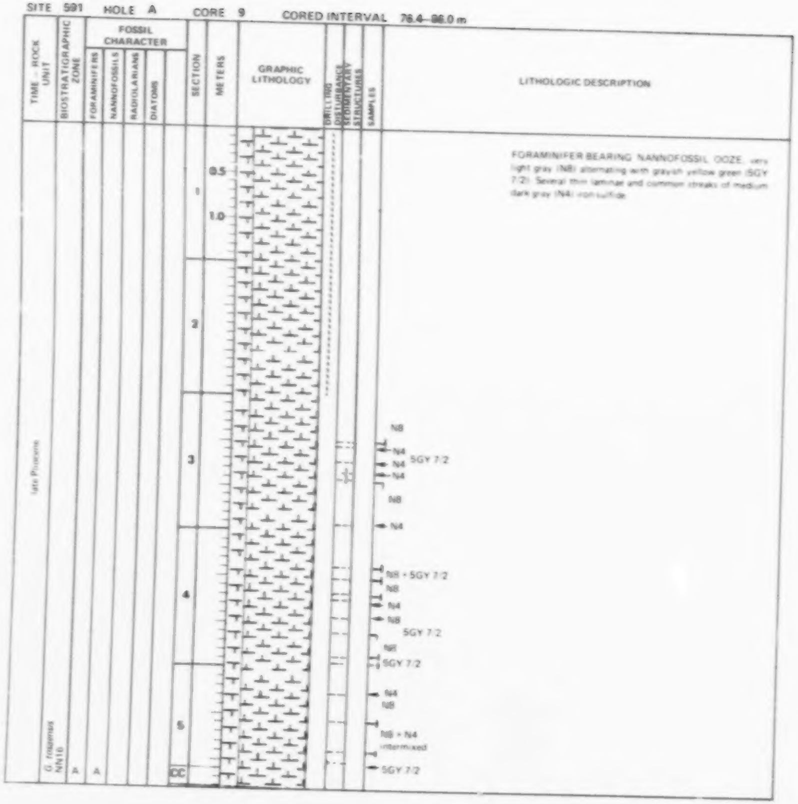
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) and grayish yellow green (5GY 7/2 and 5GY 6/2), soft, with streaks of medium dark gray (N4) iron sulfide throughout. Pocket of forams and pyrite in Section 1 and light greenish gray (5Y 8/1) and medium dark gray (N4) doublets of altered ash(?) in Sections 3, 4, and 5. Rare *Planolites*-like mottles and some chemical diffusion bands of iron sulfide.

SMEAR SLIDE SUMMARY:

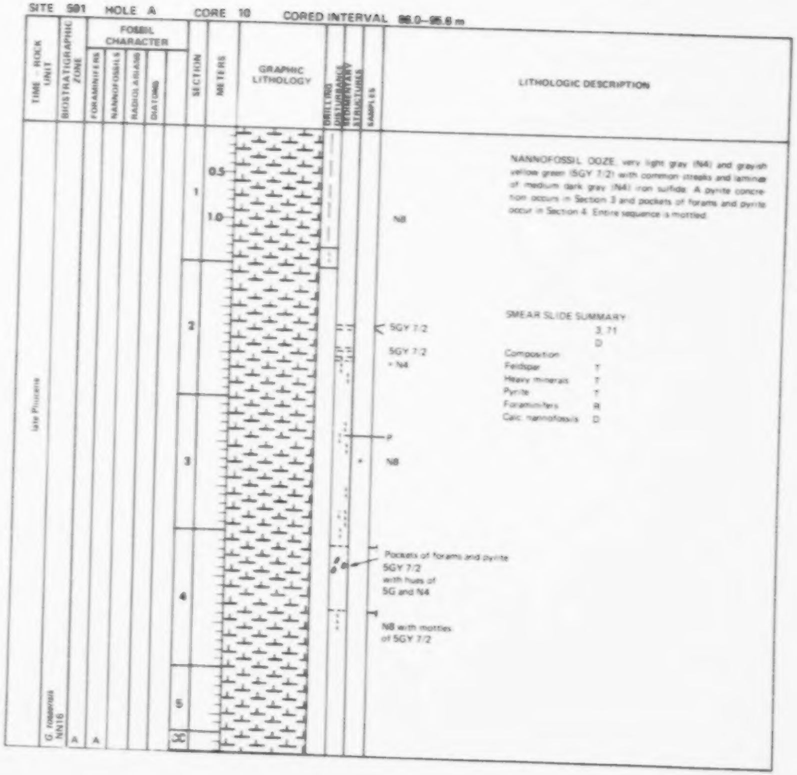
	4, 50	4, 136
	D	D
Composition:		
Quartz	–	T
Feldspar	T	T
Volcanic glass	–	T
Pyrite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D
Sponge spicules	–	T

SITE 591 HOLE A CORE 9 CORED INTERVAL 76.4–86.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
G. tosaensis
NN16
A
A
0.5
1.0
1
2
3
4
5
CC
N8
N4
N4
N4
5GY 7/2
N8
N4
N8 + 5GY 7/2
N8
N4
N8
5GY 7/2
N8
5GY 7/2
N4
N8
N8 + N4
intermixed
5GY 7/2

FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (N8) alternating with grayish yellow green (5GY 7/2). Several thin laminae and common streaks of medium dark gray (N4) iron sulfide.

SITE 591 HOLE A CORE 10 CORED INTERVAL 86.0–95.6 m

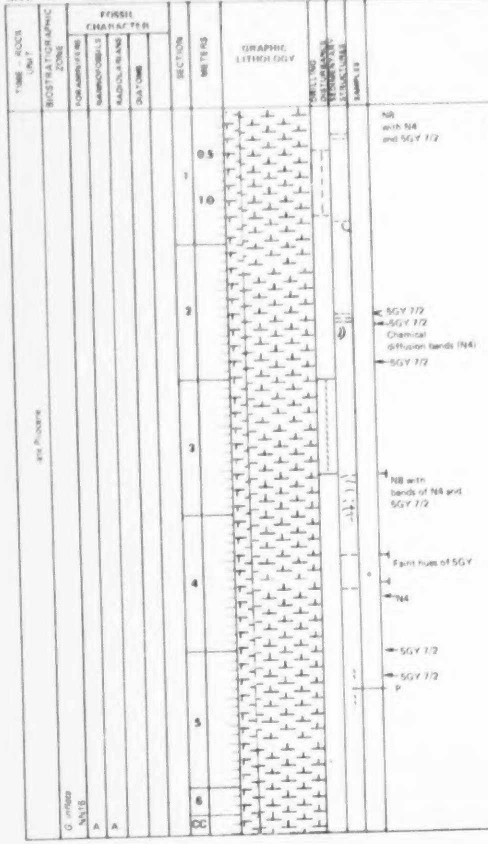

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
G. tosaensis
NN16
A
A
0.5
1.0
1
2
3
4
5
CC
N8
5GY 7/2
5GY 7/2
+ N4
P
N8
Pockets of forams and pyrite
5GY 7/2
with hues of
5G and N4
N8 with mottles
of 5GY 7/2

NANNOFOSSIL OOZE, very light gray (N4) and grayish yellow green (5GY 7/2) with common streaks and laminae of medium dark gray (N4) iron sulfide. A pyrite concretion occurs in Section 3 and pockets of forams and pyrite occur in Section 4. Entire sequence is mottled.

SMEAR SLIDE SUMMARY

	3, 71
	D
Composition:	
Feldspar	T
Heavy minerals	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 591 HOLE A CORE 11 CORED INTERVAL 95.6–105.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN15
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8 with N4 and 5GY 7/2
5GY 7/2
5GY 7/2
Chemical diffusion bands (N4)
5GY 7/2
N8 with bands of N4 and 5GY 7/2
Faint hues of 5GY
N4
5GY 7/2
5GY 7/2
P

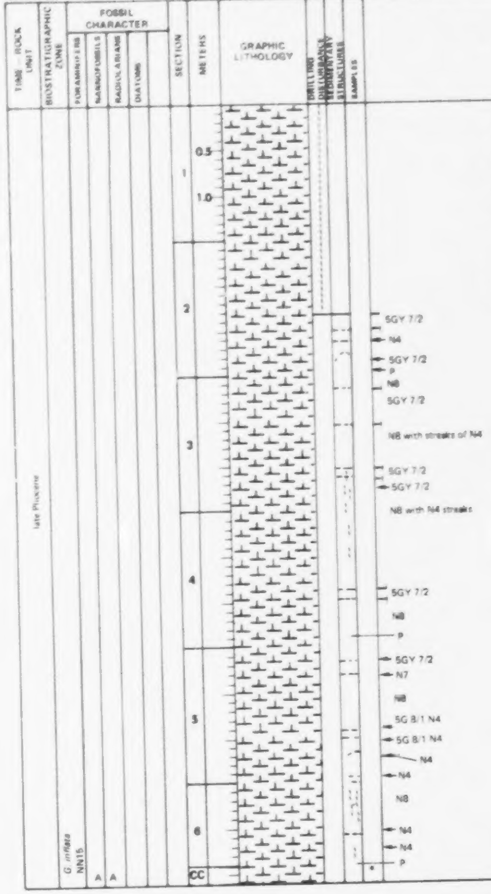
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with zones of intermixed medium dark gray (N4) and grayish yellow green (5GY 7/2). Streaks of N4 common. Faint hues of 5GY common. Mottles of 5GY 7/2 common. Thin laminae of N4 occur.

SMEAR SLIDE SUMMARY

	4, 72
Composition:	
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 591 HOLE A CORE 12 CORED INTERVAL 105.2–114.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN15
A
A
0.5
1.0
1
2
3
4
5
6
CC
5GY 7/2
N4
5GY 7/2
P
N8
5GY 7/2
N8 with streaks of N4
5GY 7/2
5GY 7/2
N8 with N4 streaks
5GY 7/2
N8
P
5GY 7/2
N7
N8
5G 8/1 N4
5G 8/1 N4
N4
N4
N8
N4
N4
P

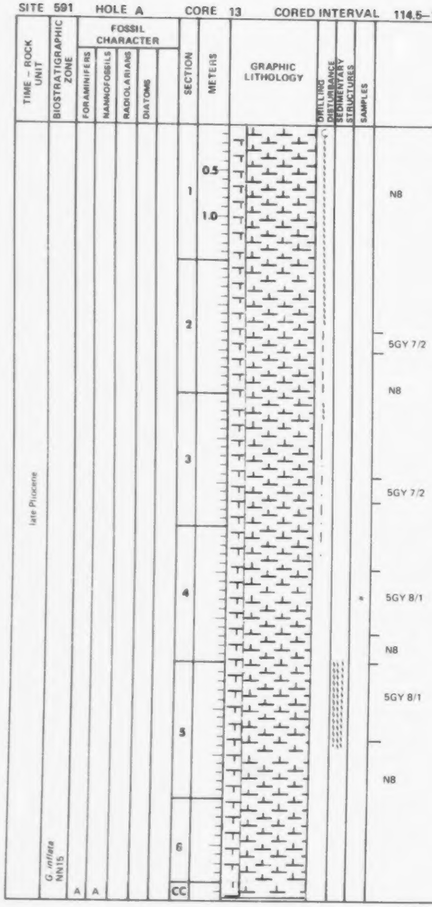
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft to firm, homogeneous except for common streaks of medium dark gray (N4), iron sulfide, thin bands of N4, grayish yellow green (5GY 7/2) and light greenish gray (5G 8/1). Large *Planolites*-like mottles of 5GY 7/2 commonly occur below Section 1. Bioturbation is common and distinctive.

SMEAR SLIDE SUMMARY

	CC D
Composition:	
Feldspar	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 591 HOLE A CORE 13 CORED INTERVAL 114.5–123.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN15
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 7/2
N8
5GY 7/2
5GY 8/1
N8
5GY 8/1
N8

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, predominantly very light gray (N8), firm, homogeneous.

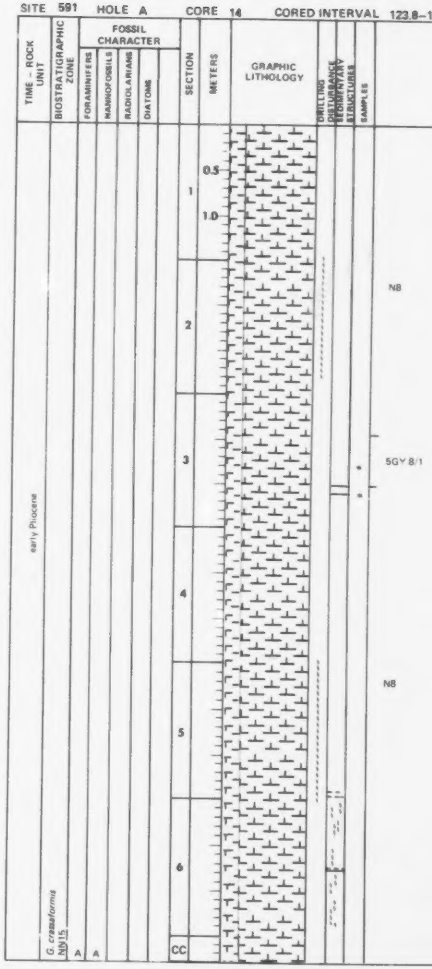
Specks, streaks, and thin bands of iron sulfides (dark to light gray [N4–N6]) and mottles of burrows (grayish yellow green [5GY 7/2]) common.

Total bioturbation.

SMEAR SLIDE SUMMARY:

	4, 80 D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Quartz	T
Feldspar	T
Mica	T
Foraminifers	C
Calc. nannofossils	D

SITE 591 HOLE A CORE 14 CORED INTERVAL 123.8–133.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 8/1
N8

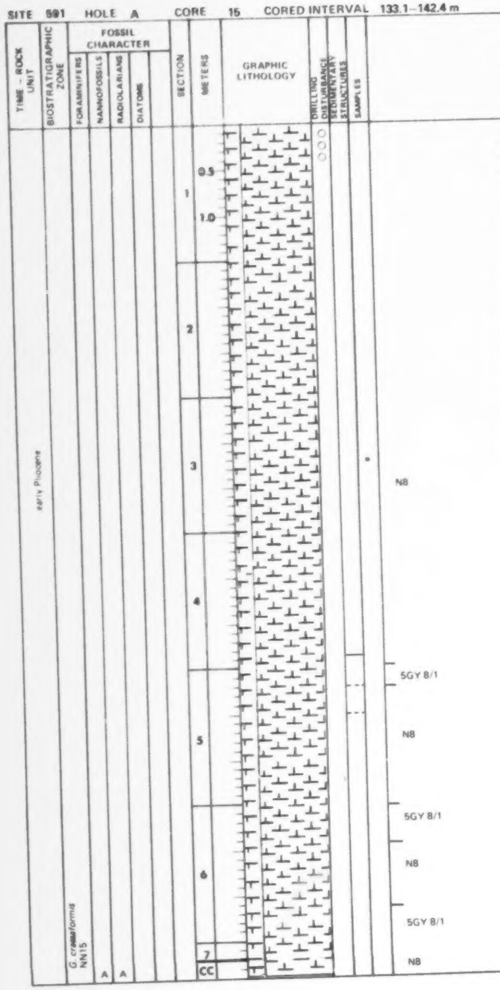
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, totally bioturbated.

SMEAR SLIDE SUMMARY:

	3, 80 D	3, 110 M
Texture		
Sand	T	R
Silt	C	R
Clay	D	D
Composition		
Quartz	T	T
Feldspar	T	T
Mica	T	–
Heavy minerals	–	T
Pyrite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D
Radiolarians	T	–
Sponge spicules	T	T

SITE 591 HOLE A CORE 15 CORED INTERVAL 133.1–142.4 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N8

LITHOLOGIC DESCRIPTION

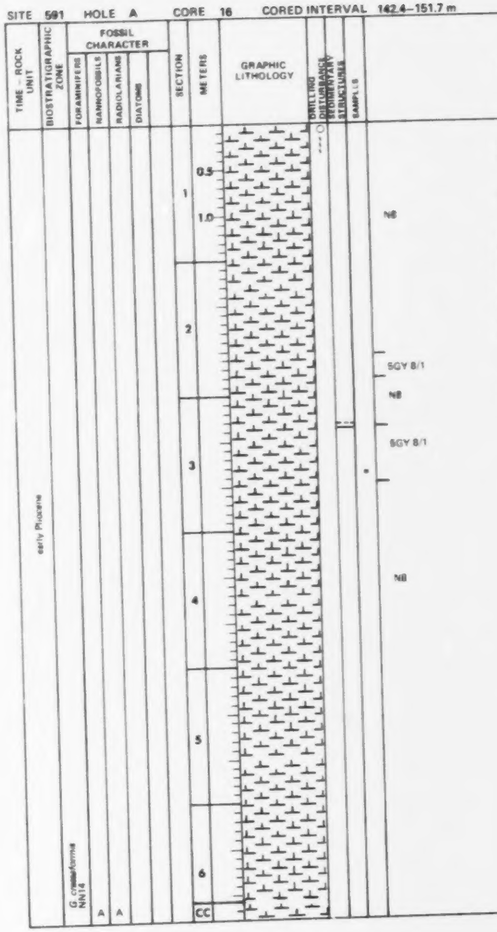
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, homogenized by multiple (superposed) bioturbation, specks and streaks of iron sulfides (dark to light gray [N4–N8]) are common.

Planolites-like mottles commonly occur throughout the core.

SMEAR SLIDE SUMMARY

	3, 70
	D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Quartz	T
Mica	T
Heavy minerals	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D
Sponge spicules	T

SITE 591 HOLE A CORE 16 CORED INTERVAL 142.4–151.7 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN14
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 8/1
N8
5GY 8/1
N8

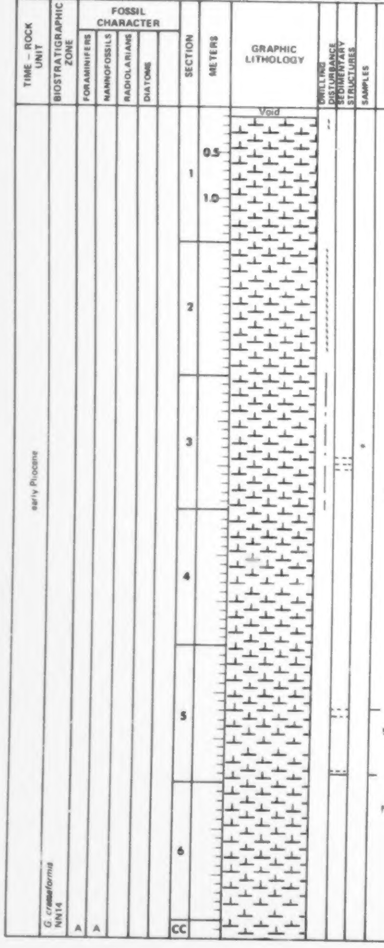
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, totally bioturbated *Planolites*-like mottles are superposed.

SMEAR SLIDE SUMMARY

	3, 84
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Feldspar	T
Heavy minerals	T
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE A CORE 17 CORED INTERVAL 151.7–161.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. crassaformis
NN14
A
A
Void
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 8/1
N8

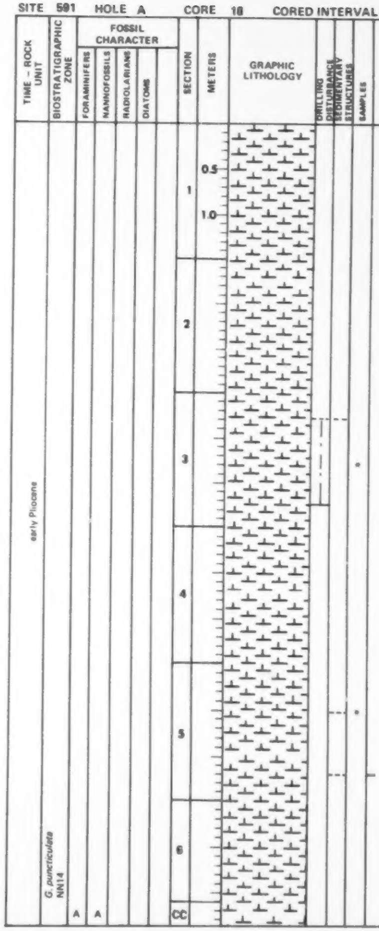
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous except for pyritized rims of trace fossils.

SMEAR SLIDE SUMMARY

	3, 75
	D
Texture	
Sand	T
Silt	T
Clay	D
Composition	
Quartz	T
Mica	T
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 591 HOLE A CORE 18 CORED INTERVAL 161.0–170.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN14
A
A
0.5
1.0
1
2
3
4
5
6
CC

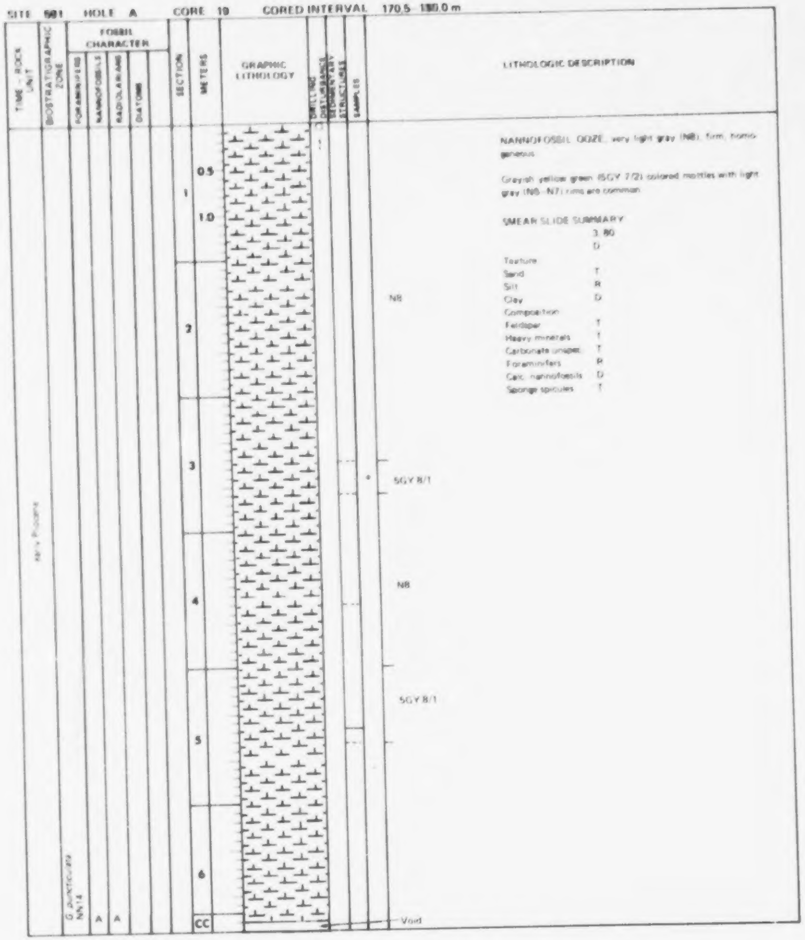
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous.

Grayish yellow green (5GY 7/2) colored mottles common (total bioturbation).

SMEAR SLIDE SUMMARY

	3, 80	5, 52
	D	M
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Quartz	–	T
Feldspar	T	T
Mica	T	T
Heavy minerals	T	T
Volcanic glass	T	T
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	T	–
Sponge spicules	T	–


SITE 591 HOLE A CORE 19 CORED INTERVAL 170.5–180.0 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN14
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 8/1
N8
5GY 8/1
Void

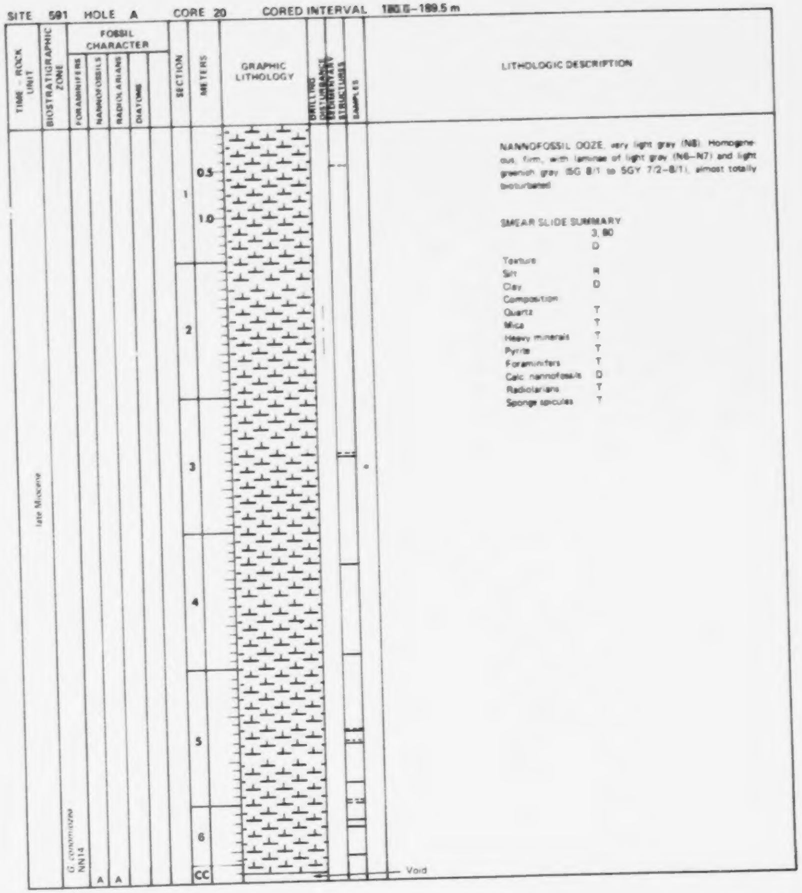
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous.

Grayish yellow green (5GY 7/2) colored mottles with light gray (N6–N7) rims are common.

SMEAR SLIDE SUMMARY

	3, 80 D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Feldspar	T
Heavy minerals	T
Carbonate unspec.	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T


SITE 591 HOLE A CORE 20 CORED INTERVAL 180.0–189.5 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN14
A
A
0.5
1.0
1
2
3
4
5
6
CC
Void

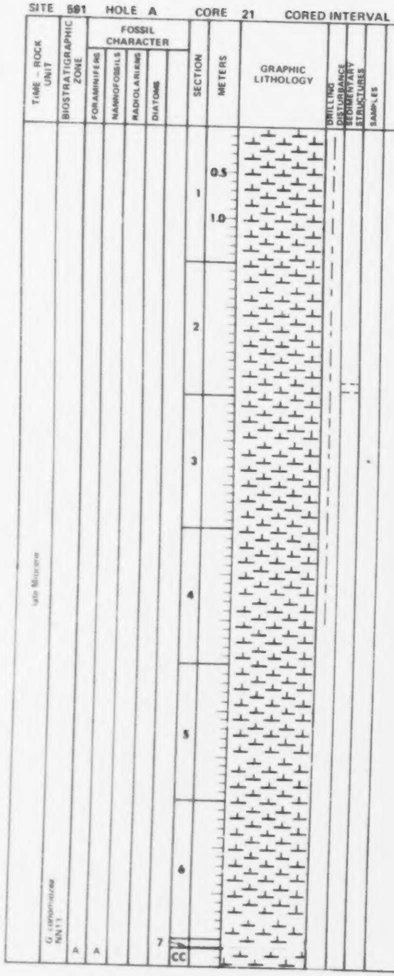
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8). Homogeneous, firm, with laminae of light gray (N6–N7) and light greenish gray (5G 8/1 to 5GY 7/2–8/1), almost totally bioturbated.

SMEAR SLIDE SUMMARY

	3, 80 D
Texture	
Silt	R
Clay	D
Composition	
Quartz	T
Mica	T
Heavy minerals	T
Pyrite	T
Foraminifers	T
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE A CORE 21 CORED INTERVAL 189.5–198.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN11
A
A
0.5
1.0
1
2
3
4
5
6
7
CC

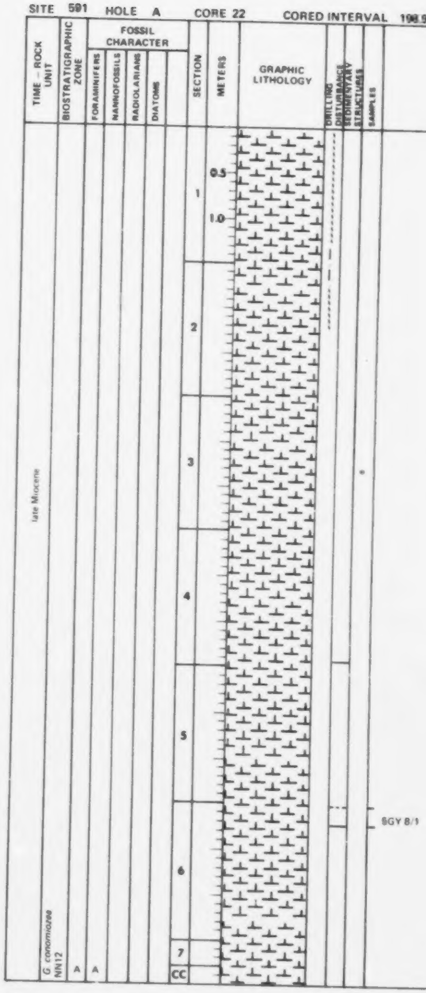
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous with specks, streaks, and mottles of medium gray (N6) and light greenish gray (5GY 8/1) to grayish yellow green (5GY 7/2), completely bioturbated.

SMEAR SLIDE SUMMARY

	3, 20
	D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Quartz	T
Feldspar	T
Heavy minerals	T
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

SITE 591 HOLE A CORE 22 CORED INTERVAL 198.9–208.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN12
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/1

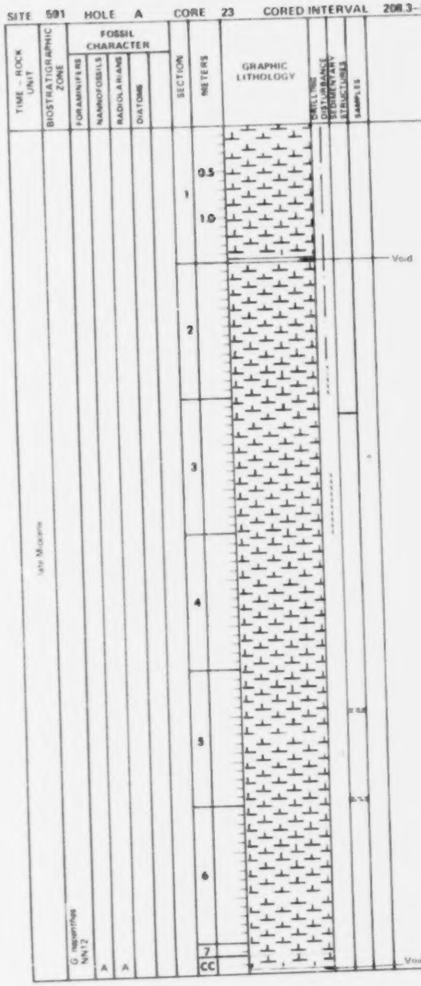
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, bioturbated and homogeneous pyritization of margin of large *Planolites*-like burrows (medium light to light gray [N6–N7]).

SMEAR SLIDE SUMMARY

	3, 80
	D
Composition	
Mica	T
Carbonate unspec.	T
Foraminifers	T
Calc. nannofossils	D
Diatoms	T

SITE 591 HOLE A CORE 23 CORED INTERVAL 208.3–217.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN12
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
Void

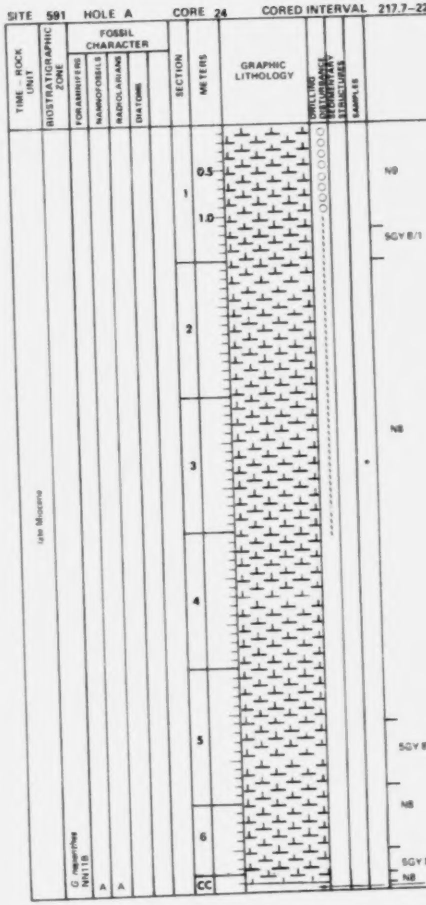
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, very homogeneous except for superposed trace fossils of giant *Planolites*-like burrows and others, and for specks and streaks of iron sulfides (medium to light grey (N6–N7)).

SMEAR SLIDE SUMMARY

	3, 75
	D
Texture	
Silt	T
Clay	D
Composition	
Pyrite	T
Carbonate unspec.	T
Foraminifers	T
Calc. nannofossils	D
Silicoflagellates	T

SITE 591 HOLE A CORE 24 CORED INTERVAL 217.7–227.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN11B
A
A
0.5
1.0
1
2
3
4
5
6
CC
N9
5GY 8/1
N8
5GY 8/1
N8
5GY 8/1
N8
Void

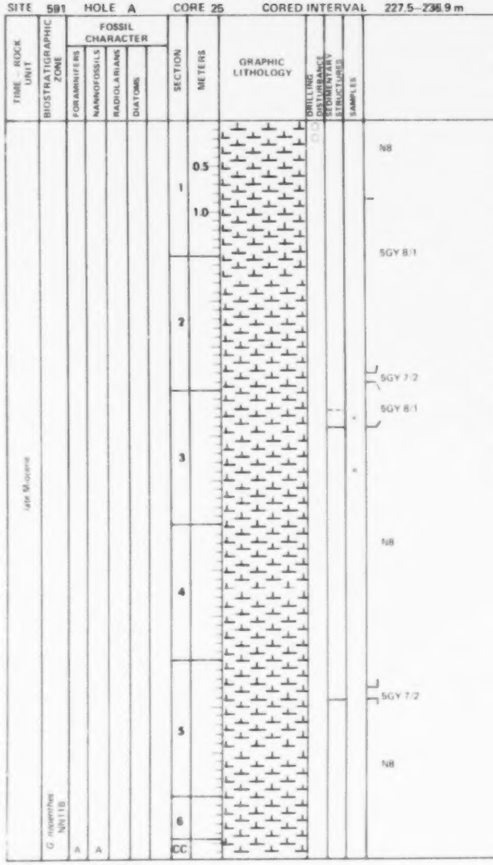
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, predominantly, very light gray (N8) and partly light greenish gray (5GY 8/1), firm but very disturbed by coring.

SMEAR SLIDE SUMMARY

	3, 80
	D
Texture	
Sand	T
Silt	T
Clay	D
Composition	
Mica	T
Volcanic glass	T
Carbonate unspec.	T
Foraminifers	T
Calc. nannofossils	D
Radiolarians	T

SITE 591 HOLE A CORE 25 CORED INTERVAL 227.5–236.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. nepenthes
NN11B
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5GY 8/1
5GY 7/2
5GY 8/1
N8
5GY 7/2
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8) to light greenish gray (5GY 8/1), firm.

Homogeneous due to bioturbation.

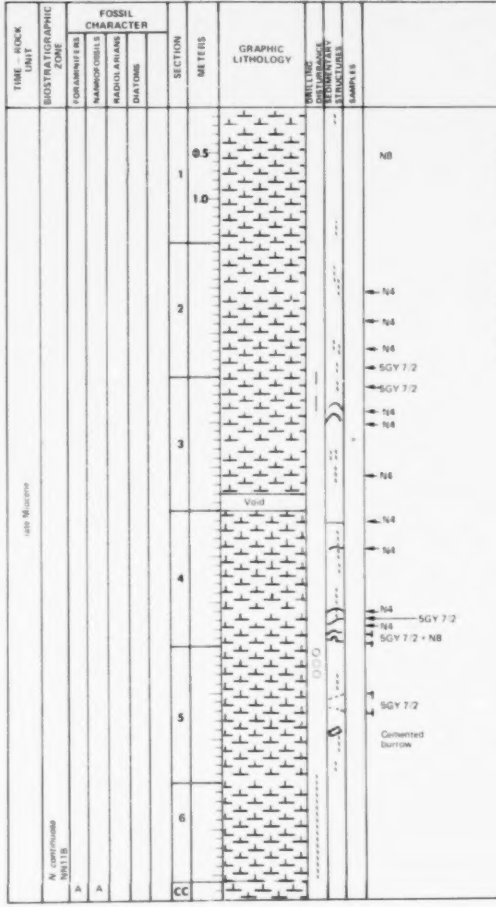
Specks of iron sulfides of medium to light gray (N4–N7) and mottles or bands of grayish yellow green (5GY 7/2) to light greenish gray (5GY 8/1) are common.

Occasionally, small pockets including volcanic glass occur (grayish olive (10Y 4/2)) at about 30 cm in Section 3.

SMEAR SLIDE SUMMARY

	3, 28	3, 80
	M	D
Texture:		
Sand	C	T
Silt	C	R
Clay	A	D
Composition:		
Quartz	T	—
Feldspar	T	T
Heavy minerals	T	T
Volcanic glass	A	—
Foraminifers	R	R
Calc. nannofossils	A	D
Diatoms	—	T
Radiolarians	—	T

SITE 591 HOLE A CORE 26 CORED INTERVAL 236.9–246.5 m

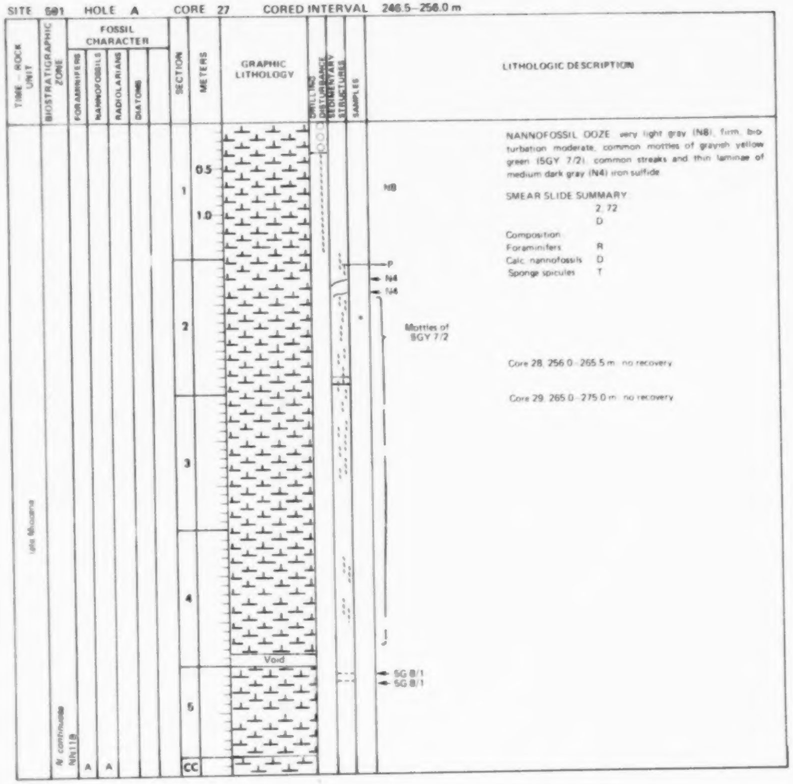

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11B
A
A
1
2
3
4
5
6
CC
0.5
1.0
Void
N8
N4
N4
N4
5GY 7/2
5GY 7/2
N4
N4
N4
N4
N4
N4
5GY 7/2
N4
5GY 7/2 + N8
5GY 7/2
Cemented burrow

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft to stiff, homogeneous, with streaks of medium dark gray (N4) iron sulfide and mottles of grayish yellow green (5GY 7/2). Bioturbation common. Cemented burrow (celestite?) in Section 5.

SMEAR SLIDE SUMMARY

	3, 72
Composition:	
Feldspar	T
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T
Sponge spicules	T


SITE 591 HOLE A CORE 27 CORED INTERVAL 246.5–256.0 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N continuosa
NN11B
A
A
1
2
3
4
5
CC
0.5
1.0
Void
N8
P
N4
N4
Mottles of 5GY 7/2
5G 8/1
5G 8/1

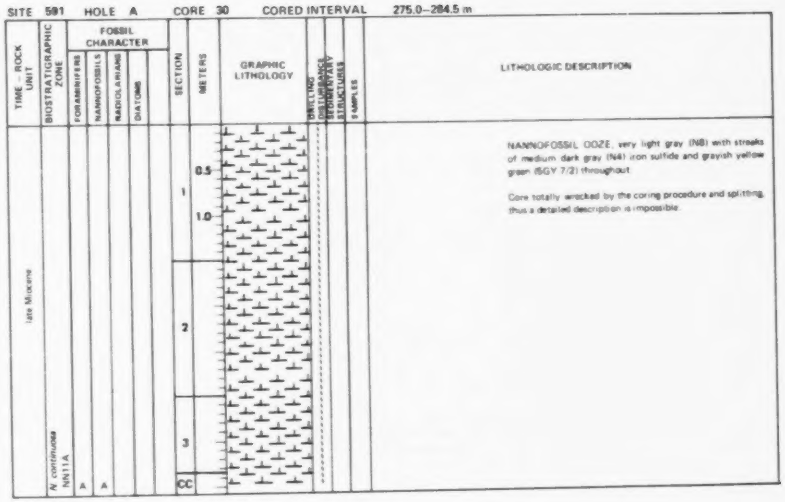
NANNOFOSSIL OOZE, very light gray (N8), firm, bioturbation moderate, common mottles of grayish yellow green (5GY 7/2), common streaks and thin laminae of medium dark gray (N4) iron sulfide.

SMEAR SLIDE SUMMARY

	2, 72
	D
Composition:	
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

Core 28, 256.0–265.5 m: no recovery

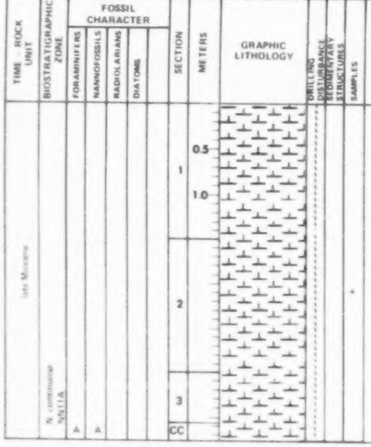
Core 29, 265.0–275.0 m: no recovery


SITE 591 HOLE A CORE 30 CORED INTERVAL 275.0–284.5 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N continuosa
NN11A
A
A
1
2
3
CC
0.5
1.0

NANNOFOSSIL OOZE, very light gray (N8) with streaks of medium dark gray (N4) iron sulfide and grayish yellow green (5GY 7/2) throughout.

Core totally wrecked by the coring procedure and splitting, thus a detailed description is impossible.

SITE 591 HOLE B CORE 1 CORED INTERVAL 270.6–280.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
CC
0.5
1.0

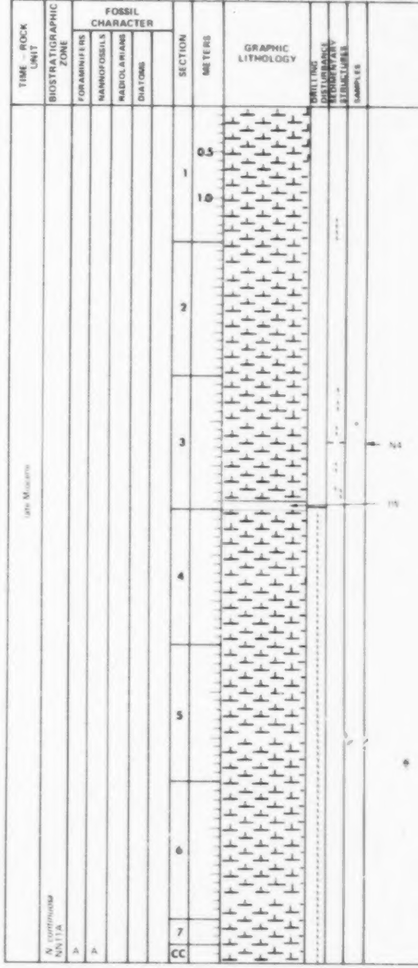
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogenized by rotary coring, streaks of medium dark gray (N4) and blobs of grayish yellow green (5GY 7/2) scattered throughout.

SMEAR SLIDE SUMMARY

	2, 69
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T

SITE 591 HOLE B CORE 2 CORED INTERVAL 280.2–289.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N4

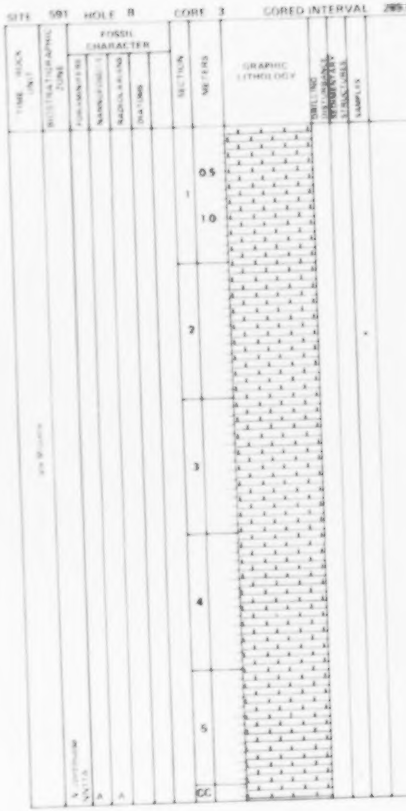
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous with a few streaks of medium dark gray (N4) iron sulfide. Severe drilling disturbance below Section 3. Small nodule of CHERT, light gray (N7) at Section 5, 145 cm – working half.

SMEAR SLIDE SUMMARY

	3, 61
	D
Composition:	
Palagonite	T
Pyrite	T
Zeolite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 591 HOLE B CORE 3 CORED INTERVAL 289.8–299.4 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
0.5
1.0
1
2
3
4
5
CC
*

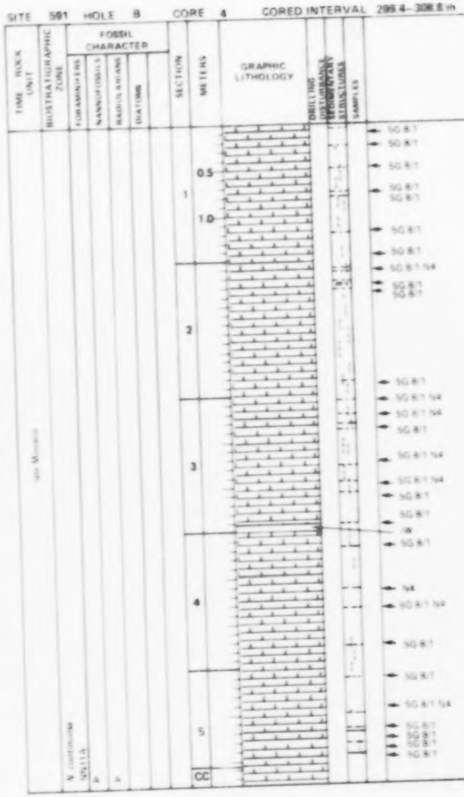
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8) with spots of medium dark gray (N4) iron sulfides. Core is broken into "biscuits" and "drilling slurry" throughout. Nannofossils show overgrowths.

SMEAR SLIDE SUMMARY

	3, 85
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T
Sponge spicules	T
Silicoflagellates	T

SITE 591 HOLE B CORE 4 CORED INTERVAL 299.4–308.8 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
0.5
1.0
1
2
3
4
5
CC
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1 N4
5G 8/1
5G 8/1
5G 8/1
5G 8/1 N4
5G 8/1 N4
5G 8/1
5G 8/1 N4
5G 8/1 N4
5G 8/1
5G 8/1
IW
5G 8/1
N4
5G 8/1 N4
5G 8/1
5G 8/1
5G 8/1 N4
5G 8/1
5G 8/1
5G 8/1
5G 8/1

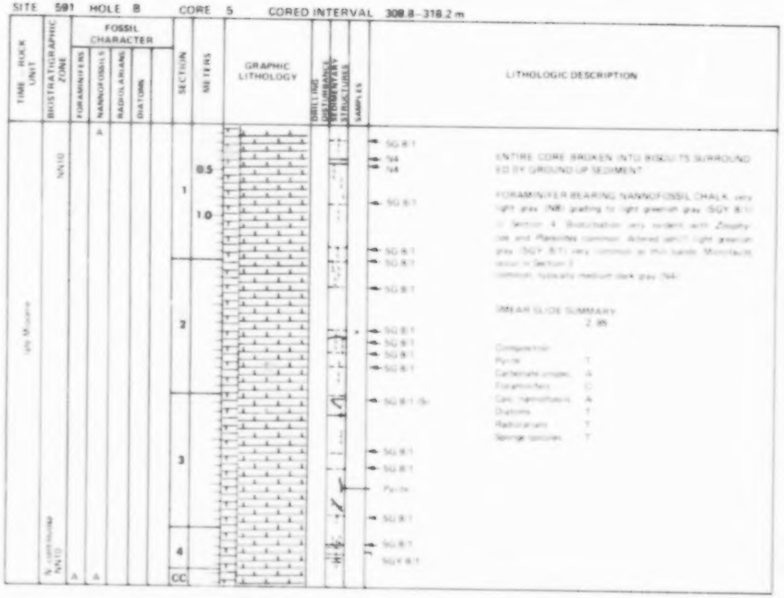
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), with common streaks, pods, and diffusion bands of medium dark gray (N4) iron sulfide. Altered ash(?) of light greenish gray (5G 8/1) color is common in very faint bands. Often a band of N4 is beneath the 5G 8/1. Burrows are very common and include *Zoophycos* and *Planolites*.

SMEAR SLIDE SUMMARY

	3, 92
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T
Sponge spicules	T
Silicoflagellates	T

SITE 591 HOLE B CORE 5 CORED INTERVAL 308.8–318.2 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN10
N. continuus NN10
A
A
A
1
2
3
4
CC
0.5
1.0
5G 8/1
N4
N4
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1 (5r
5G 8/1
5G 8/1
Pyrite
5G 8/1
5G 8/1
5GY 8/1

LITHOLOGIC DESCRIPTION

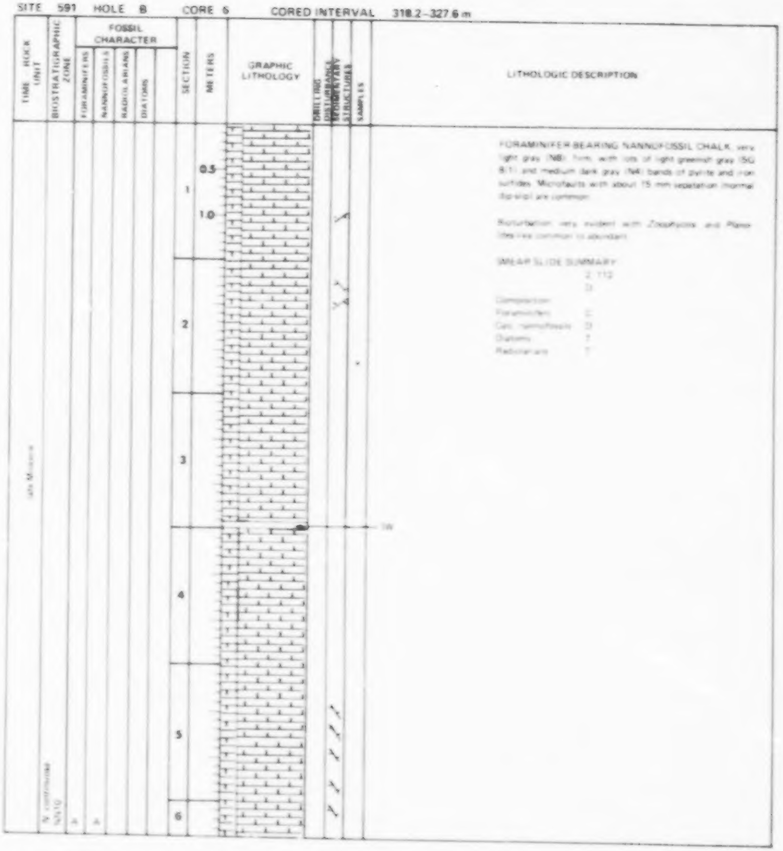
ENTIRE CORE BROKEN INTO BISCUITS SURROUNDED BY GROUND-UP SEDIMENT.

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) grading to light greenish gray (5GY 8/1) in Section 4. Bioturbation very evident with *Zoophycos* and *Planolites* common. Altered (ash?) light greenish gray (5GY 8/1) very common as thin bands. Microfaults occur in Section 3.
common, typically medium dark gray (N4).

SMEAR SLIDE SUMMARY

	2, 85
Composition:	
Pyrite	T
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A
Diatoms	T
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE B CORE 6 CORED INTERVAL 318.2–327.6 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuus NN10
A
A
1
2
3
4
5
6
0.5
1.0
IW

LITHOLOGIC DESCRIPTION

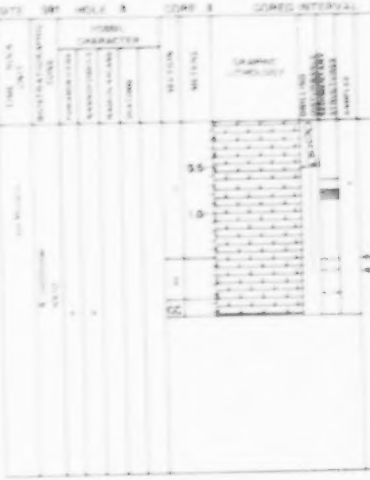
FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), firm, with lots of light greenish gray (5G 8/1) and medium dark gray (N4) bands of pyrite and iron sulfides. Microfaults with about 15 mm separation (normal dip-slip) are common.

Bioturbation very evident with *Zoophycos* and *Planolites*-like common to abundant.

SMEAR SLIDE SUMMARY

	2, 112 D
Composition:	
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Radiolarians	T

SITE 591 HOLE B CORE 8 CORED INTERVAL 337.2–346.8 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
0.5
1.0
CC
Parallel lamina
5G 8/1
5G 6/2
10G 6/2
5G 8/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light green (5BG [illegible]) to white (N9), soft due to coring to firm.

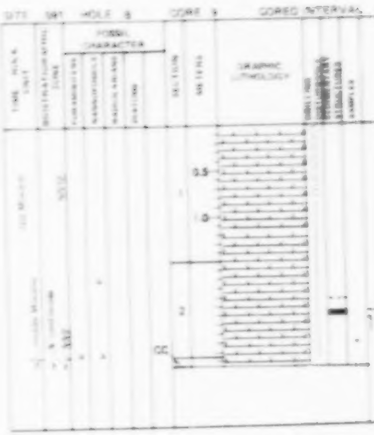
Bioturbated structure (burrows) are less abundant than in Core 7.

Parallel pale green (10G [illegible]) thin laminae remarkable.

SMEAR SLIDE SUMMARY
1, 70
D

Texture
Sand –
Silt [illegible]
Clay [illegible]
Composition
Heavy minerals [illegible]
Volcanic glass –
Pyrite –
Carbonate unspec. –
Foraminifers [illegible]
Calc. nannofossils D
Diatoms T
Radiolarians T
Sponge spicules T

SITE 591 HOLE B CORE 9 CORED INTERVAL 346.8–356.4 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
0.5
1.0
CC
5G 5/2

LITHOLOGIC DESCRIPTION

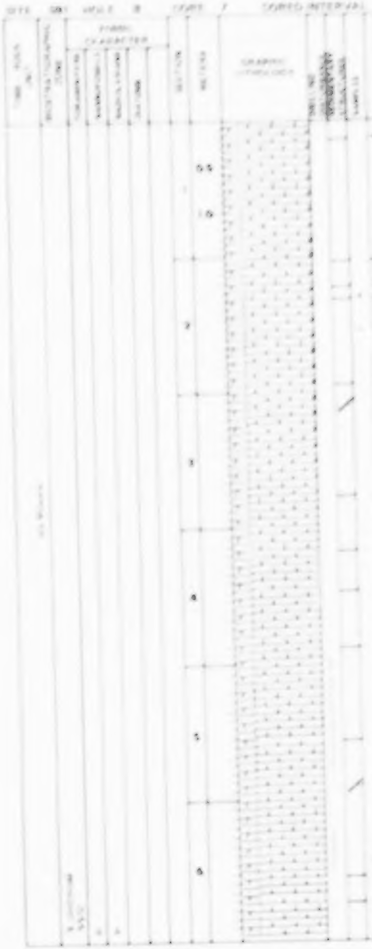
Very disturbed by coring (poor recovery).

NANNOFOSSIL CHALK, very light gray (N8), greenish, mainly soft by coring except for biscuits of firm sediment with parallel lamination of thin grayish green (5G 5/2) laminae.

SMEAR SLIDE SUMMARY
2, 60
D

Texture
Sand –
Silt [illegible]
Clay [illegible]
Composition
Quartz –
Volcanic glass –
Carbonate unspec. A
Foraminifers [illegible]
Calc. nannofossils D
Radiolarians T

SITE 591 HOLE B CORE 7 CORED INTERVAL 327.8–337.2 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
0.5
1.0
2
3
4
5
6

LITHOLOGIC UNIT DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), [illegible] with [illegible] of light greenish gray (5G 8/1, [illegible]) laminae and parallel [illegible] bands of (5G 8/1) and light gray (N7).

Light greenish gray bands composed of parallel laminae, partially [illegible].

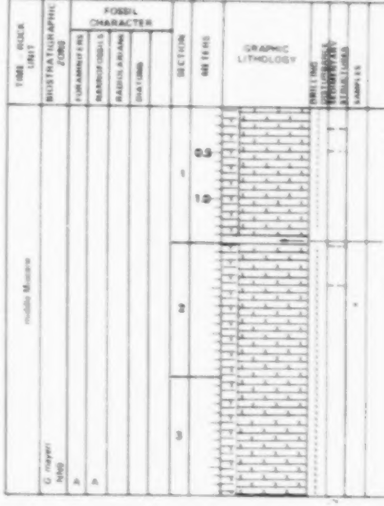
Bioturbation: [illegible], Zoophycos, Planolites [illegible].

[illegible]

SMEAR SLIDE SUMMARY
1, 94 / 2, 60 / 3, 80

Texture
Sand
Silt
Clay
Composition
Quartz
Feldspar
Volcanic glass
Pyrite
Carbonate unspec.
Foraminifers
Calc. nannofossils
Diatoms
Radiolarians
Sponge spicules

SITE 591 HOLE B CORE 10 CORED INTERVAL 356.4–366.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN8
A
A
1
2
3
0.5
1.0

LITHOLOGIC DESCRIPTION

5G 7/2
5G 7/2
IW
5G 8/1
5G 7/2

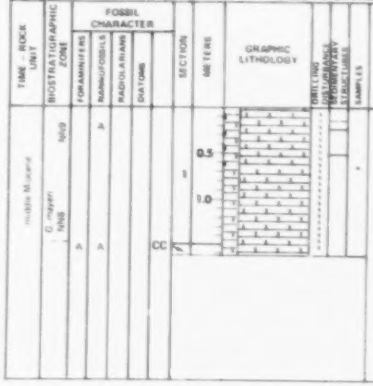
Very disturbed by coring.

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) to white (N9) with thin lamina of pale green (5G 7/2) to light greenish gray (5G 8/1).

SMEAR SLIDE SUMMARY

	2, 77
	D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Pyrite	T
Carbonate unspec.	R
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Radiolarians	T

SITE 591 HOLE B CORE 11 CORED INTERVAL 366.0–375.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN9
G. mayeri NN8
A
A
A
1
CC
0.5
1.0

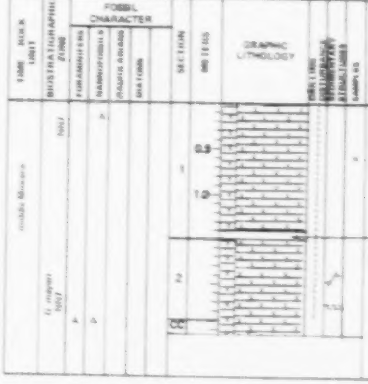
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), originally firm, with parallel thin laminae of pale green (5G 7/2).

SMEAR SLIDE SUMMARY

	1, 63
	D
Texture	
Sand	T
Silt	C
Clay	D
Composition	
Feldspar	T
Heavy minerals	T
Carbonate unspec.	T
Foraminifers	C
Calc. nannofossils	D
Radiolarians	T

SITE 591 HOLE B CORE 12 CORED INTERVAL 375.6–385.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN7
G. mayeri NN7
A
A
A
1
2
CC
0.5
1.0

LITHOLOGIC DESCRIPTION

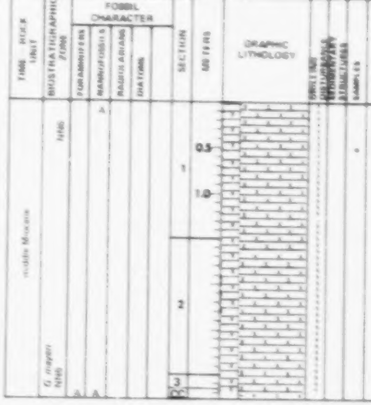
IW

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) to white (N9), naturally firm, very disturbed by coring with very thin laminae of dusky green (5G 3/2).

SMEAR SLIDE SUMMARY

	1, 90
	D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Feldspar	T
Pyrite	T
Carbonate unspec.	T
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Sponge spicules	T

SITE 591 HOLE B CORE 13 CORED INTERVAL 385.2–394.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN8
G. mayeri NN8
A
A
A
1
2
3
CC
0.5
1.0

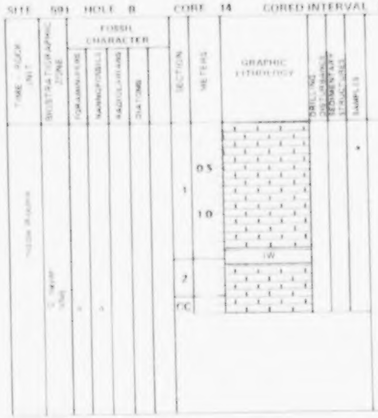
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light greenish gray (5GY 8/1–N8), biscuits with very thin laminae of grayish green (5G 5/2) and pyrite and iron sulfides of grayish purple (5P 4/2).

SMEAR SLIDE SUMMARY

	1, 50
	D
Texture	
Sand	T
Silt	C
Clay	D
Composition	
Quartz	T
Carbonate unspec.	R
Foraminifers	C
Calc. nannofossils	D
Radiolarians	T

SITE 591 HOLE B CORE 14 CORED INTERVAL 394.8–404.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
1
2
CC
0.5
1.0
IW

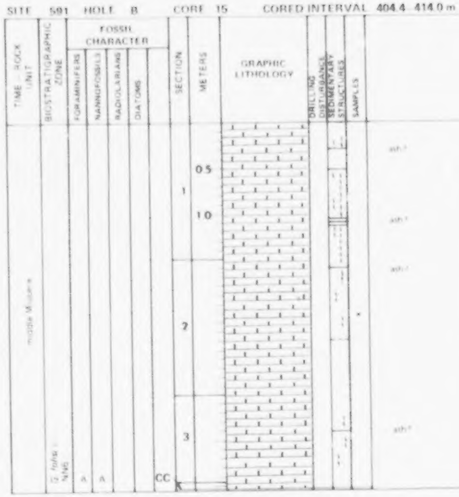
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), firm bis-cuits and soft slurry; very disturbed by coring and piece recovery; with thin laminae of light greenish gray (5G 8/1) and grayish blue (5PB 5/2); pyrite specks; burrows of *Zoophycos* and *Chondrites* etc.

SMEAR SLIDE SUMMARY:

	1, 31
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Feldspar	T
Heavy minerals	T
Carbonate unspec.	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE B CORE 15 CORED INTERVAL 404.4–414.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
1
2
3
CC
0.5
1.0
ash?
ash?
ash?
ash?

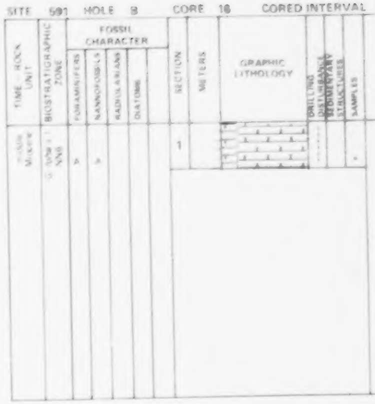
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), firm; moderate drilling disturbance, with lots of trace fossils and green laminae. *Zoophycos* and *Planolites*-like burrows are present.

SMEAR SLIDE SUMMARY:

	2, 70
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Quartz	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE B CORE 16 CORED INTERVAL 414.0–423.6 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
1

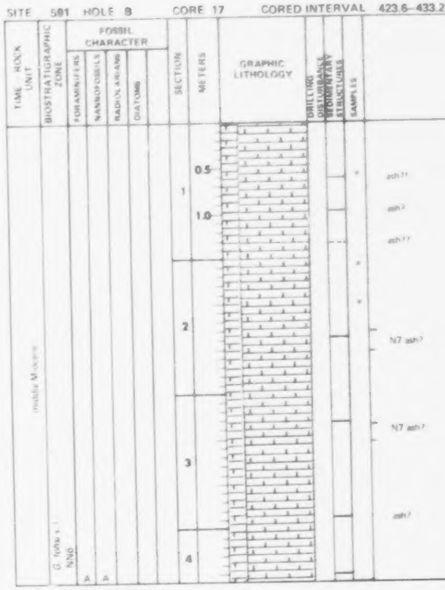
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) to light gray (N7); completely bioturbed with dense piles of burrow lenses.

SMEAR SLIDE SUMMARY:

	1, 62
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Quartz	T
Pyrite	T
Carbonate unspec.	T
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Radiolarians	T

SITE 591 HOLE B CORE 17 CORED INTERVAL 423.6–433.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. fohsi s.l.
NN6
A
A
1
2
3
4
0.5
1.0
ash??
ash?
ash??
N7 ash?
N7 ash?
ash?

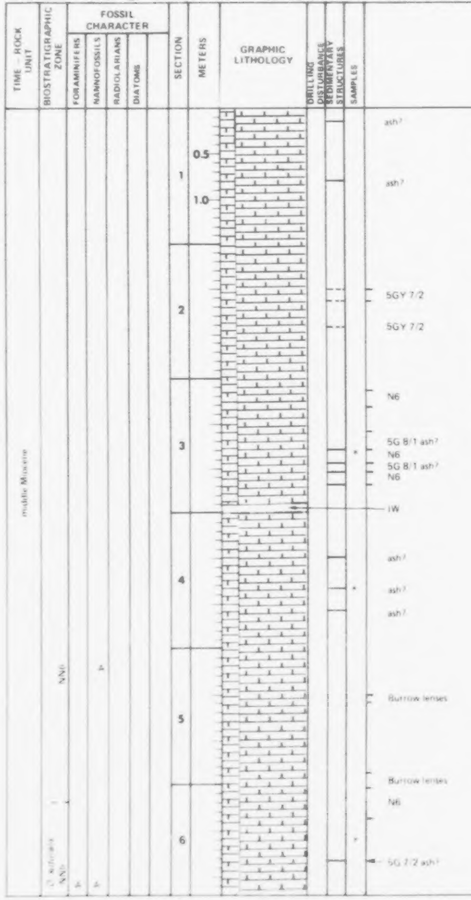
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) with a few zones of burrow lenses of light gray (N8), firm, with several zones of fine intervals of parallel laminae (grayish green (5G 5/2)).

SMEAR SLIDE SUMMARY:

	1, 53	2, 7	2, 43
	M	M	D
Texture:			
Sand	T	—	T
Silt	R	—	R
Clay	D	—	D
Composition:			
Quartz	T	—	T
Feldspar	—	—	T
Volcanic glass	T	—	—
Pyrite	—	D	—
Carbonate unspec.	T	—	T
Foraminifers	C	—	C
Calc. nannofossils	D	R	D
Diatoms	T	—	T
Radiolarians	—	—	T
Sponge spicules	—	—	T

SITE 591 HOLE B CORE 18 CORED INTERVAL 433.2–442.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
G. suturalis
NN5
A
A
A
1
2
3
4
5
6
0.5
1.0
ash?
ash?
5GY 7/2
5GY 7/2
N6
5G 8/1 ash?
N6
5G 8/1 ash?
N6
IW
ash?
ash?
ash?
Burrow lenses
Burrow lenses
N6
5G 7/2 ash?

LITHOLOGIC DESCRIPTION

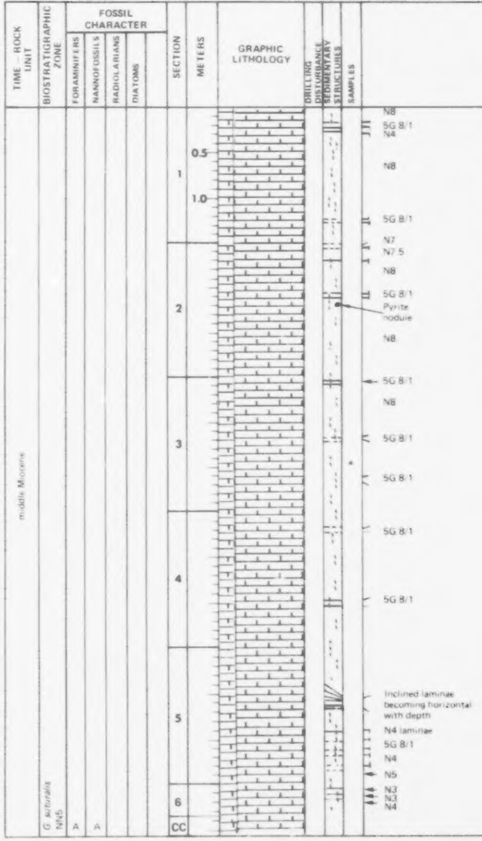
FORAMINIFER-BEARING NANNOFOSSIL CHALK, predominantly, very light gray (N8) to white (N9) with chemically changed zones of light gray (N7) to medium gray (N6). Parallel laminae of grayish green (5G 7/2) and burrow lenses typically gray (N6) common.

Bioturbation distinct.

SMEAR SLIDE SUMMARY

	3, 72	4, 91	6, 60
	D	M	D
Texture:			
Sand	T	R	R
Silt	C	C	C
Clay	D	A	D
Composition:			
Quartz	T	T	T
Pyrite	T	—	—
Carbonate unspec.	T	C	R
Foraminifers	C	A	C
Calc. nannofossils	D	A	D
Diatoms	—	T	—
Radiolarians	T	T	T
Sponge spicules	T	T	T

SITE 591 HOLE B CORE 19 CORED INTERVAL 442.8–452.4 m

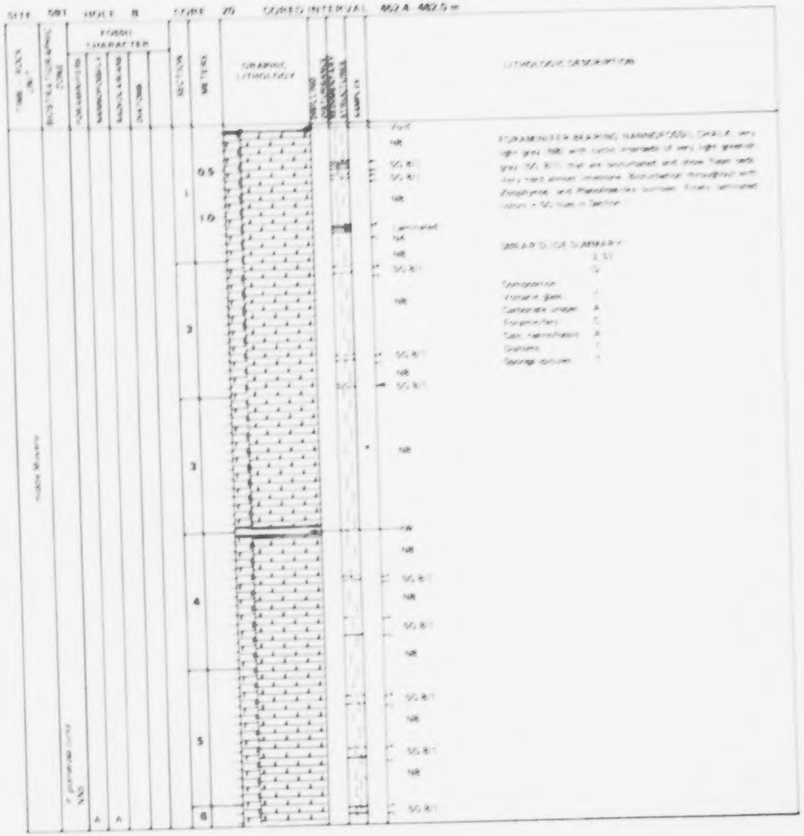

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. suturalis
NN5
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5G 8/1
N4
N8
5G 8/1
N7
N7.5
N8
5G 8/1
Pyrite nodule
N8
5G 8/1
N8
5G 8/1
5G 8/1
5G 8/1
5G 8/1
Inclined laminae becoming horizontal with depth
N4 laminae
5G 8/1
N4
N5
N3
N3
N4

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) with cycles of light greenish gray (5G 8/1), very hard, entire sequence is moderately bioturbated with *Zoophycos* and *Planolites*-like burrows. The (5G 8/1) interbeds are beginning to show flaser type structure. Pyrite nodules rare.

SMEAR SLIDE SUMMARY

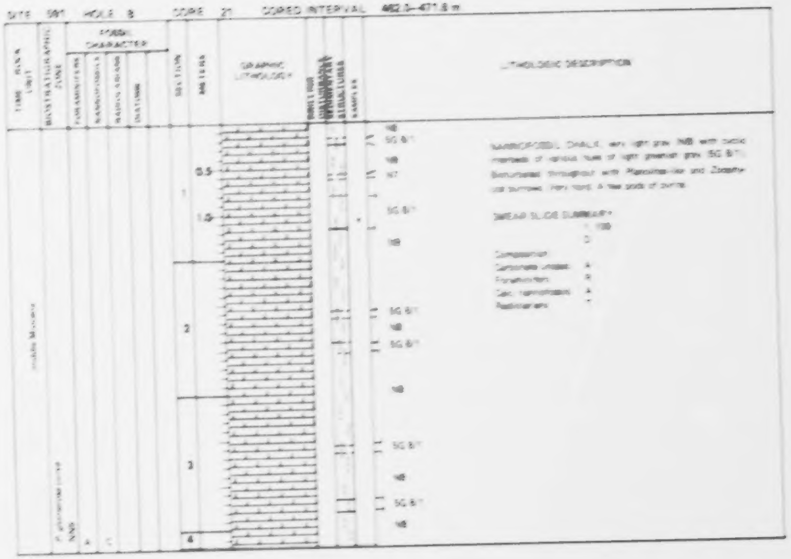
	3, 88
	D
Composition:	
Quartz	T
Volcanic glass	T
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A
Radiolarians	T
Sponge spicules	T


SITE 591 HOLE B CORE 20 CORED INTERVAL 452.4–462.0 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
P. glomerosa zone
NN5
A
A
0.5
1
1.0
2
3
4
5
6
Void
N8
5G 8/1
Laminated
N4
*

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) with cyclic intervals of very light greenish gray (5G 8/1) that are bioturbated and show fissile beds. Very hard almost limestone. Bioturbation throughout with *Zoophycos* and *Planolites*-like burrows. Finely laminated intervals in 5G hues in Section 1.

SMEAR SLIDE SUMMARY (%):

	2, 57
	D
Composition:	
Volcanic glass	T
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A
Diatoms	T
Sponge spicules	T

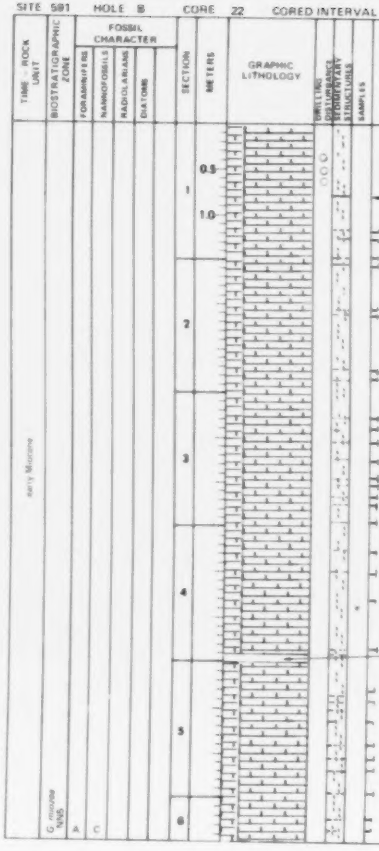

SITE 591 HOLE B CORE 21 CORED INTERVAL 462.0–471.6 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
P. glomerosa zone
NN5
A
C
0.5
1
1.0
2
3
4
N8
5G 8/1
N7
*

NANNOFOSSIL CHALK, very light gray (N8) with cyclic intervals of various hues of light greenish gray (5G 8/1). Bioturbated throughout with *Planolites*-like and *Zoophycos* burrows. Very hard. A few pods of pyrite.

SMEAR SLIDE SUMMARY (%):

	1, 100
	D
Composition:	
Carbonate unspec.	A
Foraminifers	R
Calc. nannofossils	A
Radiolarians	T

SITE 591 HOLE B CORE 22 CORED INTERVAL 471.6–481.2 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
C
0.5
1.0
1
2
3
4
5
6
5GY 8/1
N4
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
N8
5GY 8/1
5G 8/1
N8
5G 8/1
5GY 8/1
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8

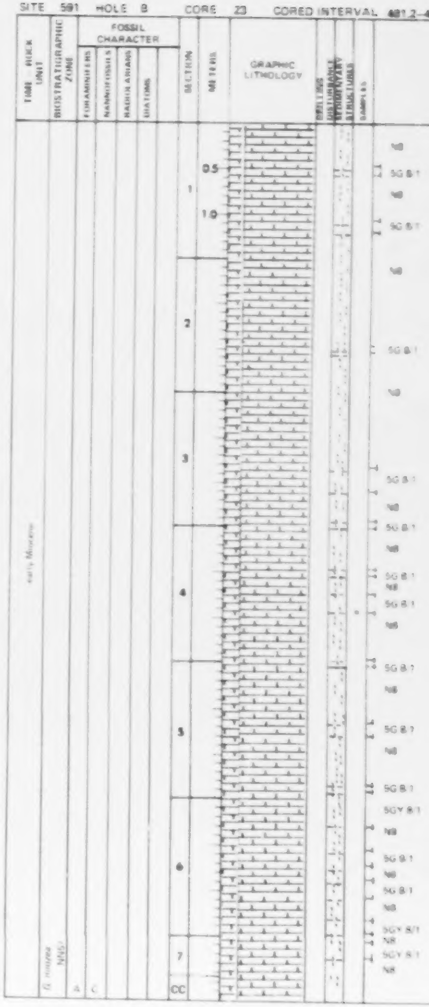
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, alternating cycles of light greenish gray (5GY 8/1 and 5G 8/1) and very light gray (N8), very hard. Bioturbated throughout. Flaser structures developed in (5G 8/1) interbeds. Iron sulfide bands rare.

SMEAR SLIDE SUMMARY

	4, 95 D
Composition	
Volcanic glass	T
Carbonate unspec	A
Foraminifers	C
Calc. nannofossils	A
Diatoms	T
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE B CORE 23 CORED INTERVAL 481.2–490.8 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
C
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
5GY 8/1
N8
5G 8/1
N8
5G 8/1
N8
5GY 8/1
N8
5GY 8/1
N8

LITHOLOGIC DESCRIPTION

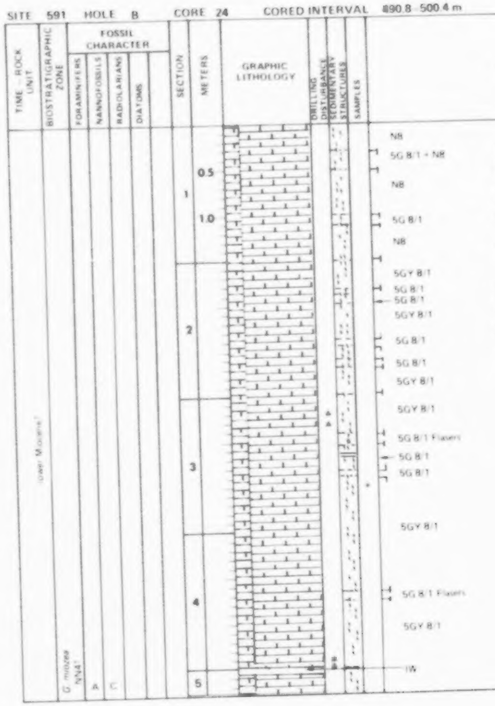
FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8) with alternating light greenish gray (5GY 8/1 and 5G 8/1). Iron sulfide streaks and spots common. Totally bioturbated and extremely hard – almost limestone.

Flaser structure developed in some (5G 8/1) interbeds.

SMEAR SLIDE SUMMARY

	4, 90 D
Composition	
Volcanic glass	T
Carbonate unspec	A
Foraminifers	C
Calc. nannofossils	A
Radiolarians	T
Sponge spicules	T

SITE 591 HOLE B CORE 24 CORED INTERVAL 490.8–500.4 m

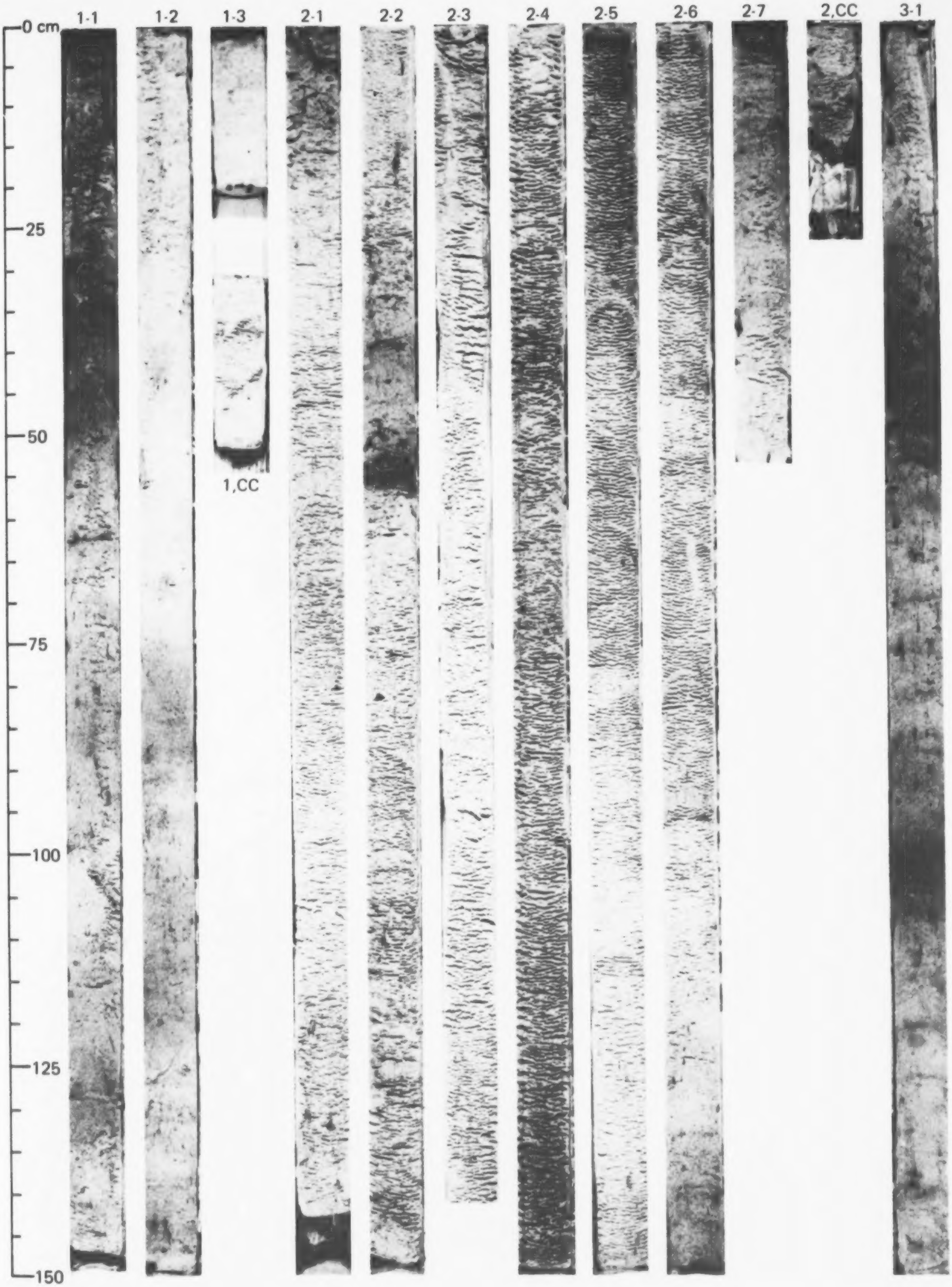

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
lower Miocene?
G. miozea
NN4?
A
C
1
2
3
4
5
0.5
1.0
N8
5G 8/1 + N8
N8
5G 8/1
N8
5GY 8/1
5G 8/1
5G 8/1
5GY 8/1
5G 8/1
5G 8/1
5GY 8/1
5GY 8/1
5G 8/1 Flasers
5G 8/1
5G 8/1
5GY 8/1
5G 8/1 Flasers
5GY 8/1
IW

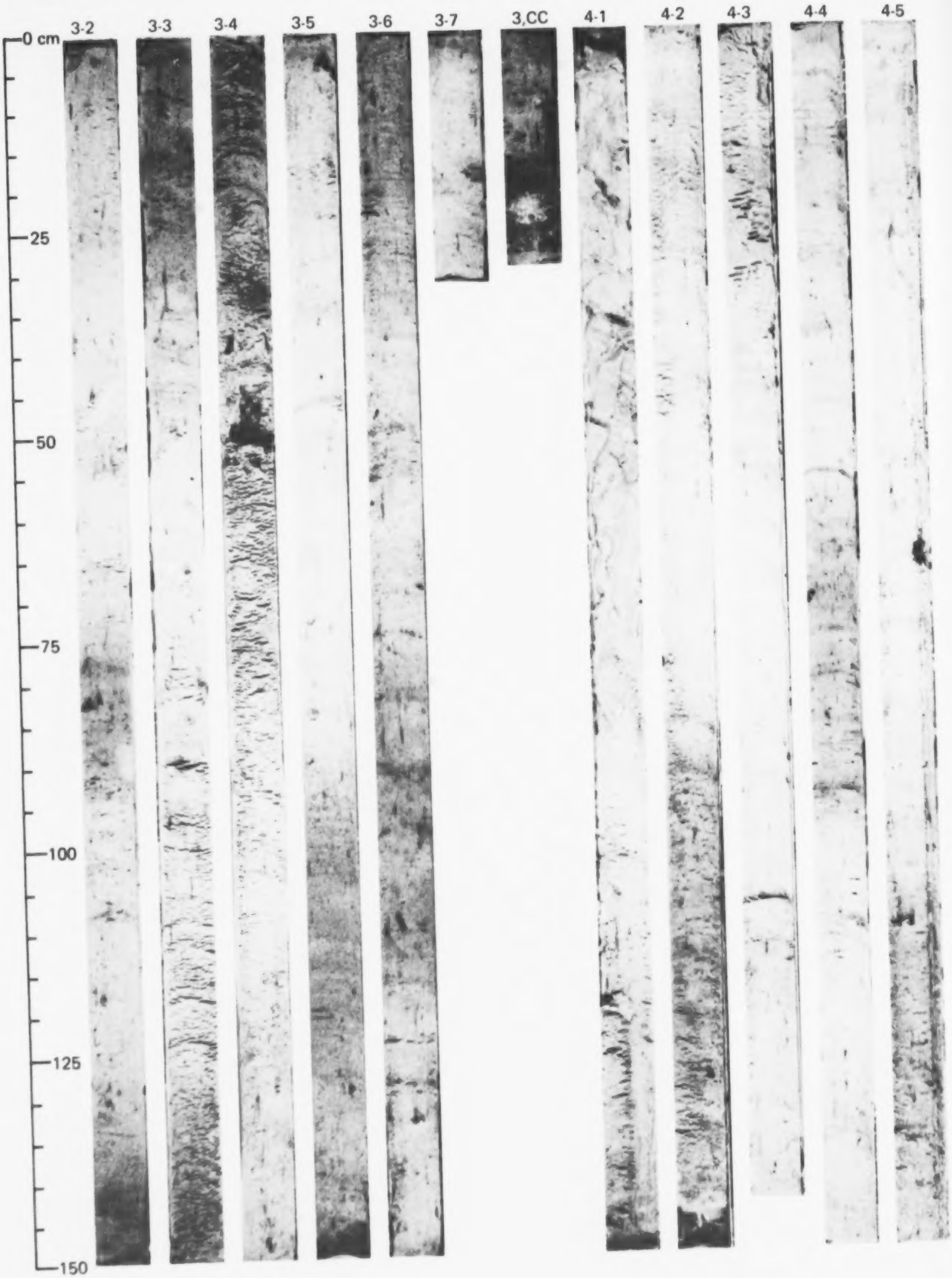
LITHOLOGIC DESCRIPTION

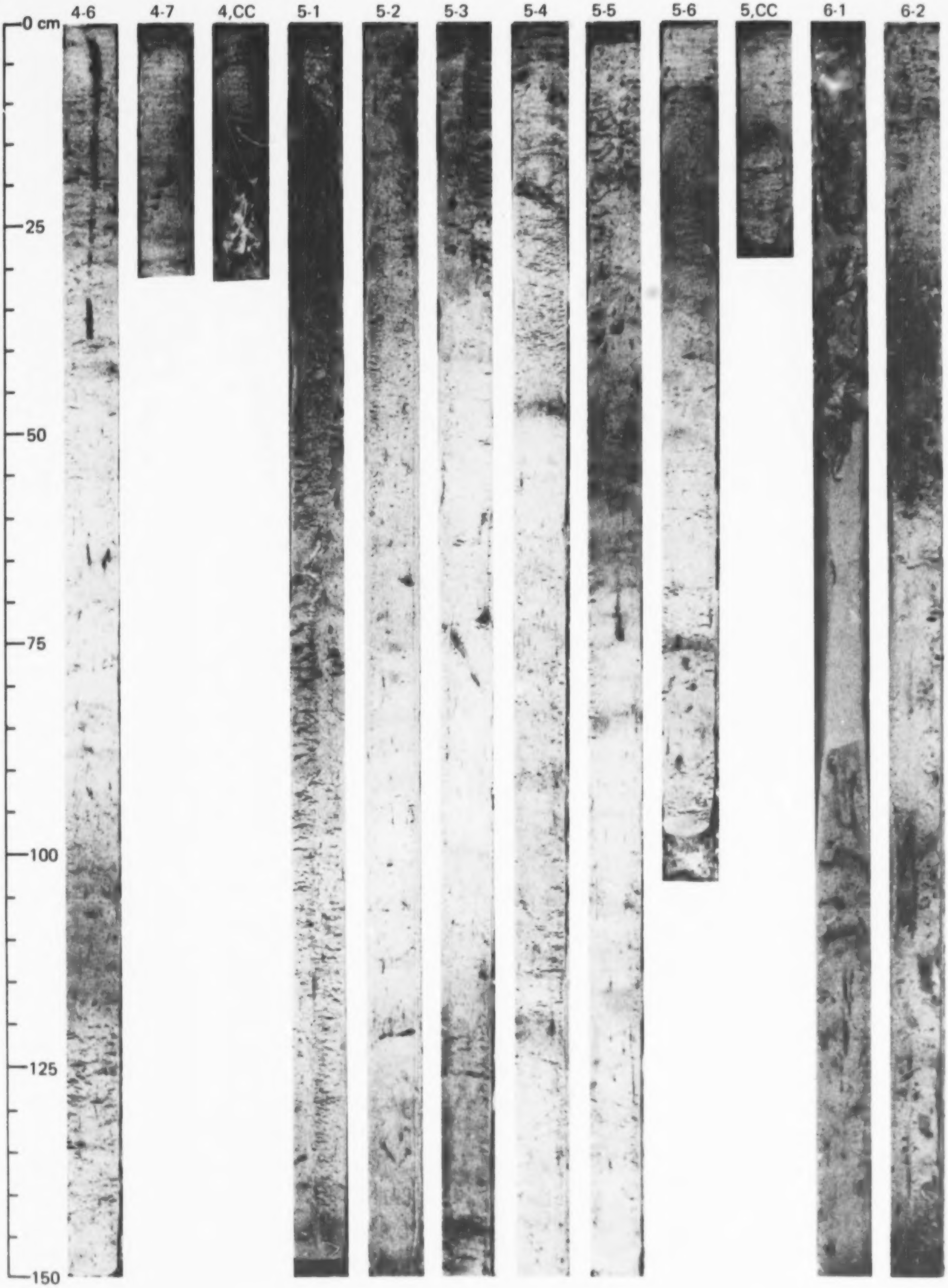
FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), light greenish gray (5GY 8/1 and 5Y 8/1) interbedded. Very hard and almost a limestone. Thoroughly bioturbated and a few zones show flaser structures. *Zoophycos* very rare. All contacts between interbeds are gradational, burrowed but horizontal.

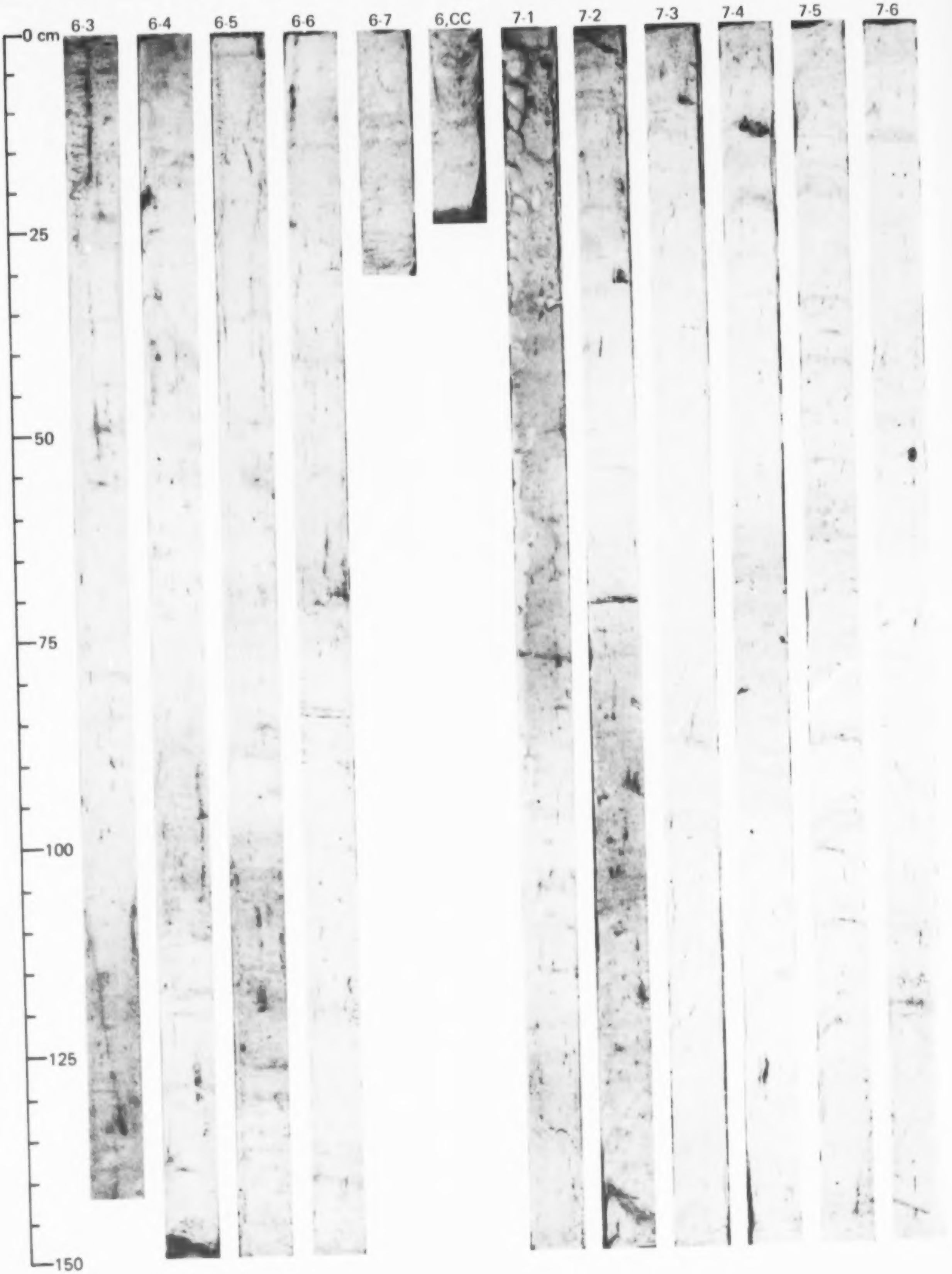
SMEAR SLIDE SUMMARY

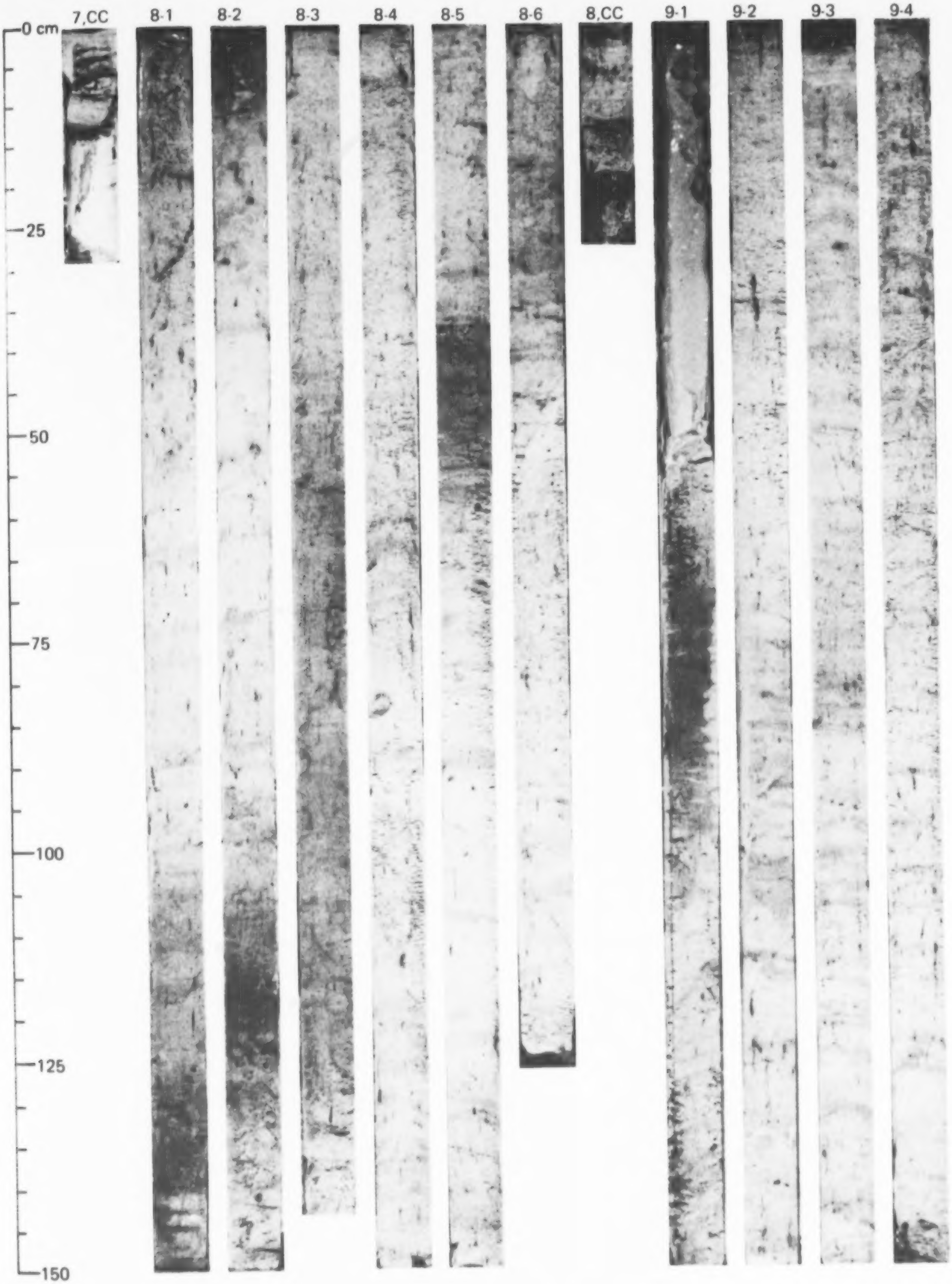
	3, 99
	D
Composition:	
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A
Sponge spicules	T

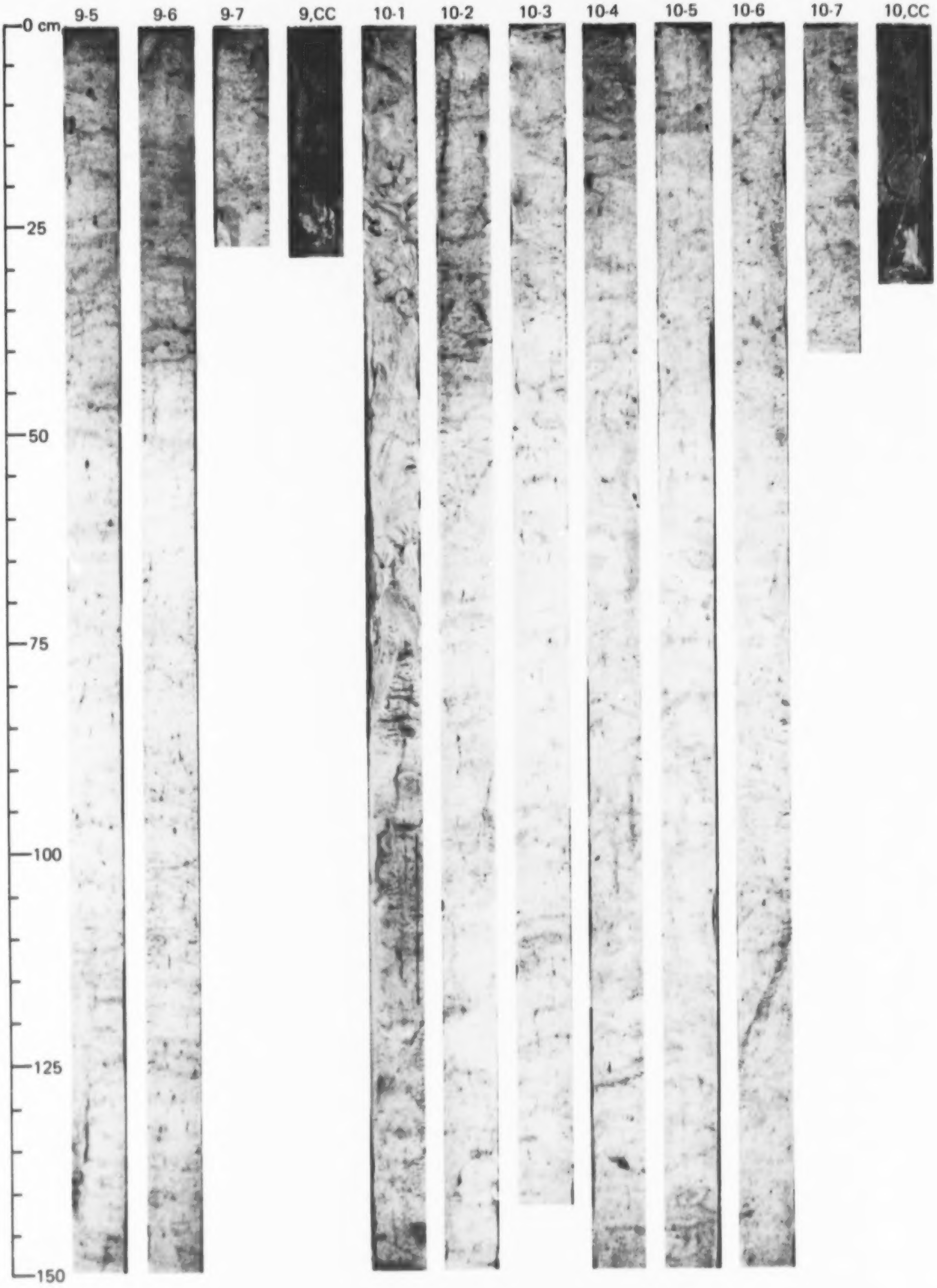

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2,CC
3-1

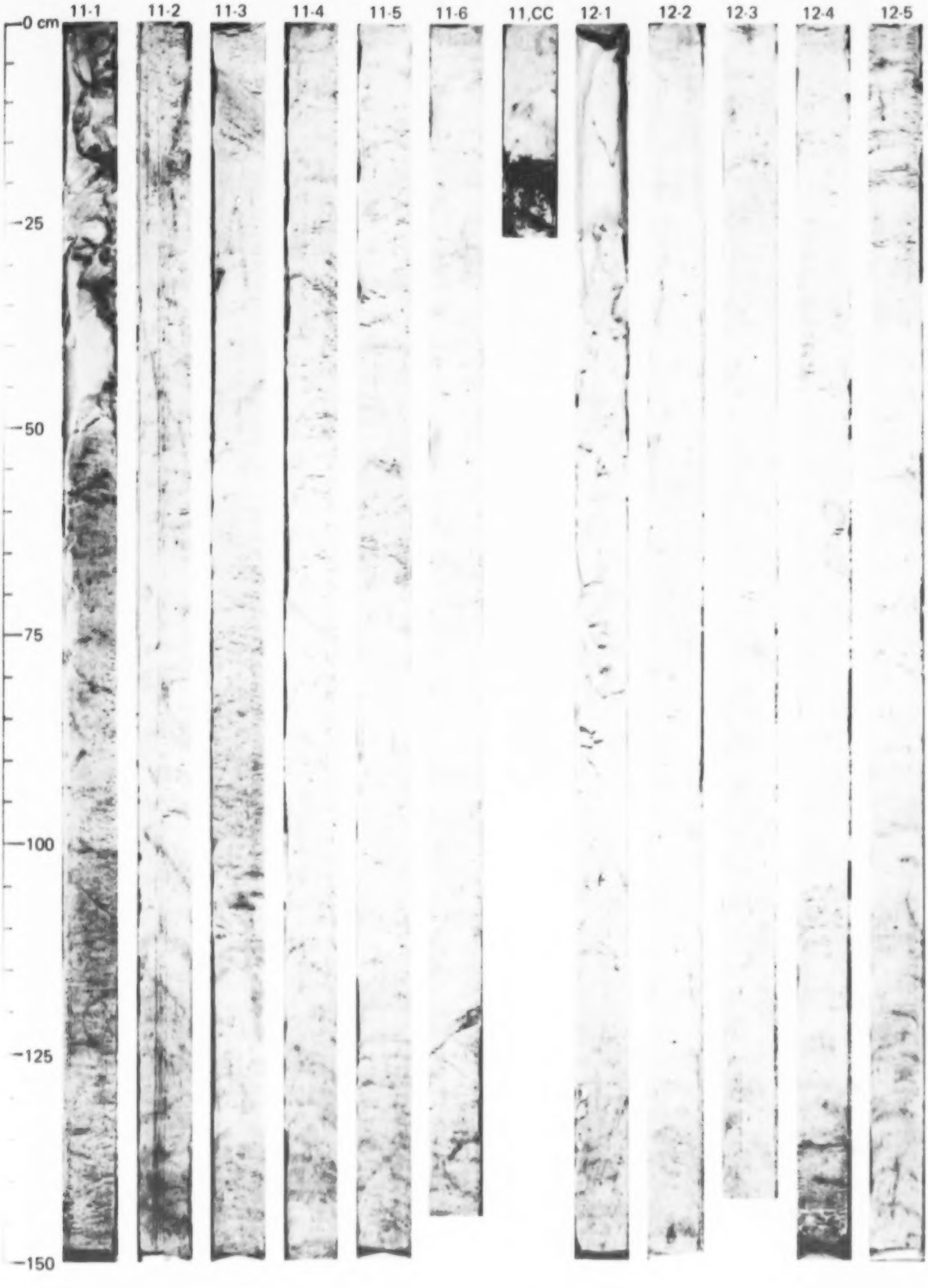

3-2
3-3
3-4
3-5
3-6
3-7
3,CC
4-1
4-2
4-3
4-4
4-5
0 cm
25
50
75
100
125
150

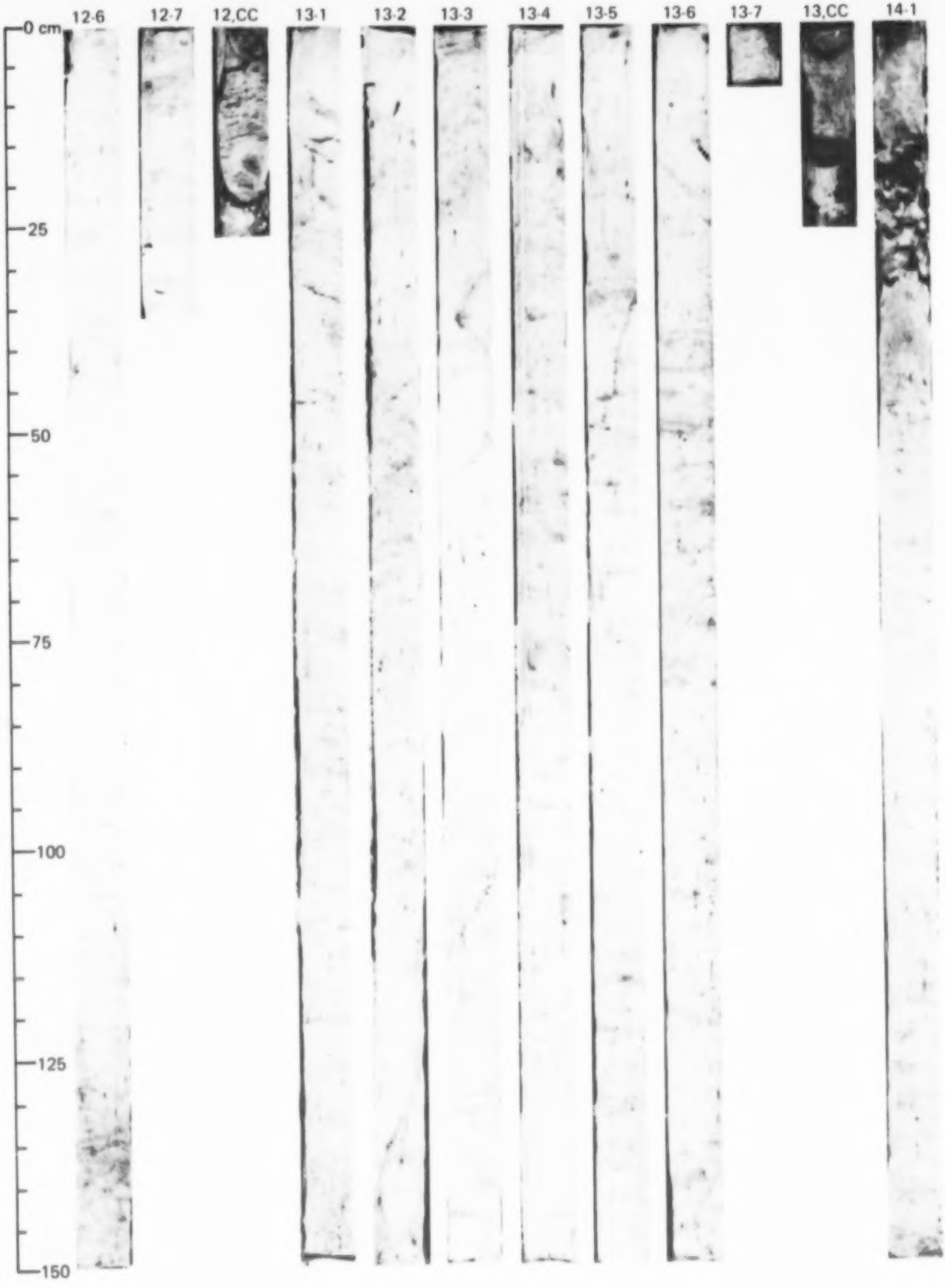

4-6
4-7
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5,CC
6-1
6-2
0 cm
25
50
75
100
125
150

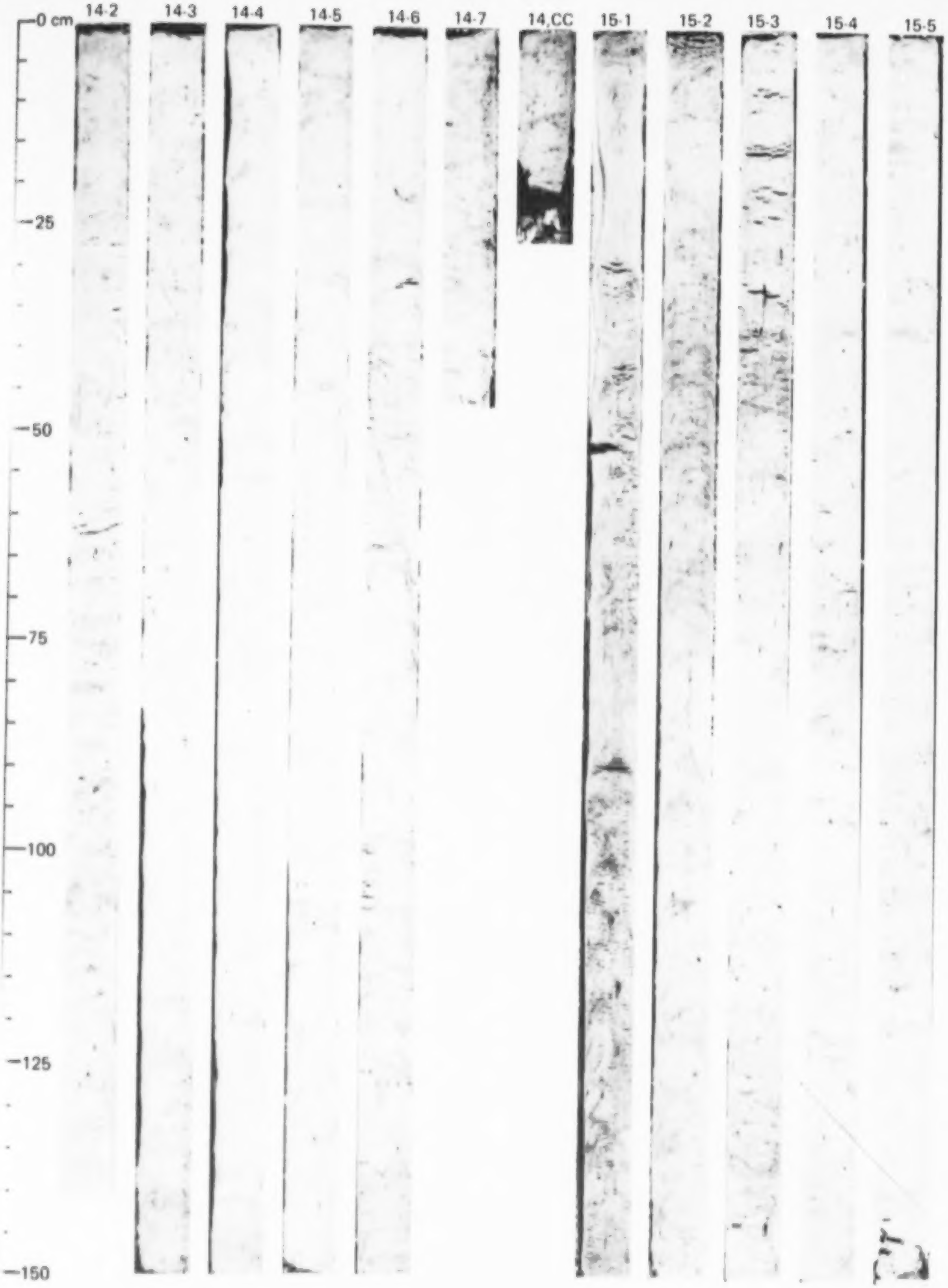

6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4
7-5
7-6
0 cm
25
50
75
100
125
150

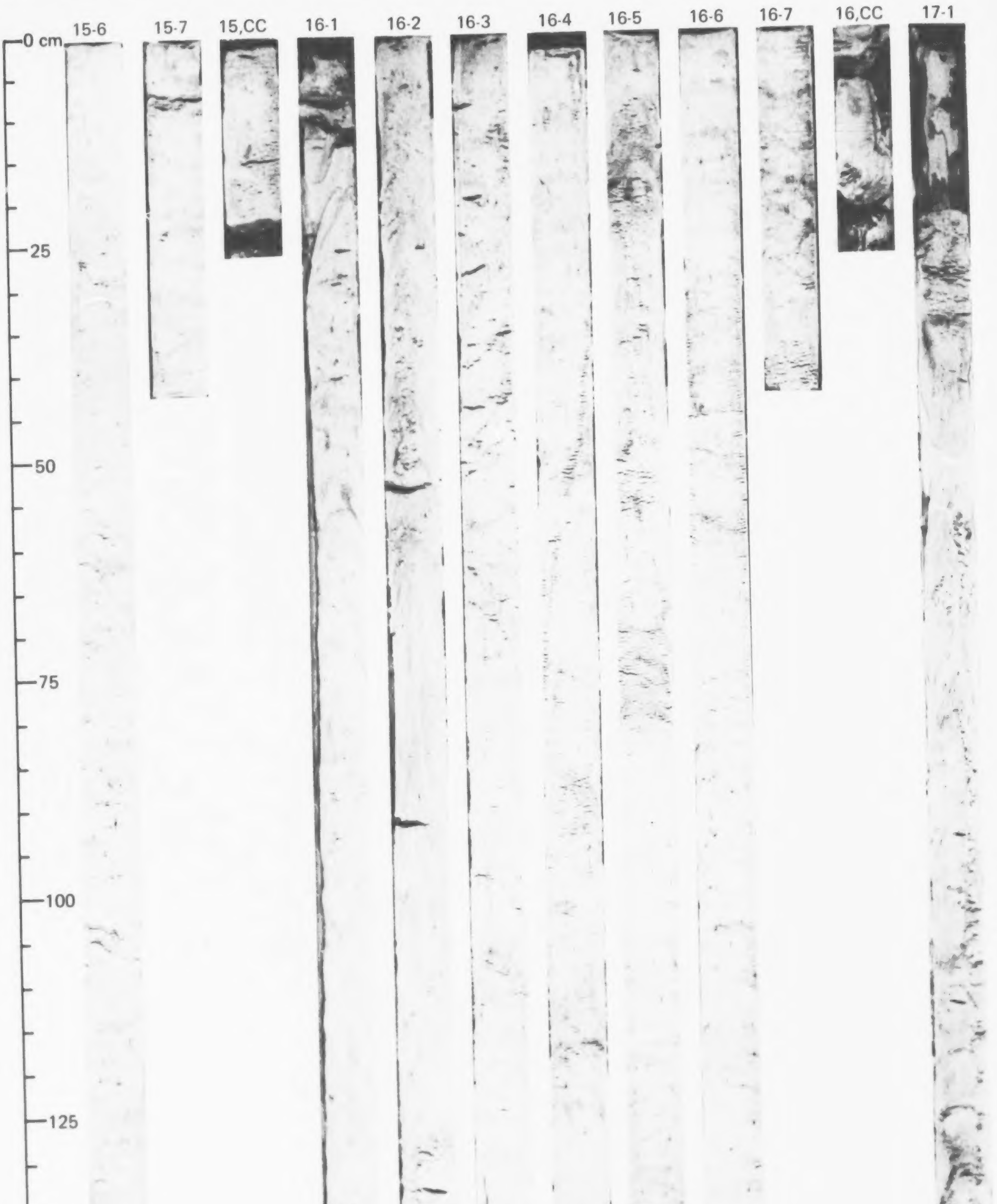

7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8,CC
9-1
9-2
9-3
9-4
0 cm
25
50
75
100
125
150

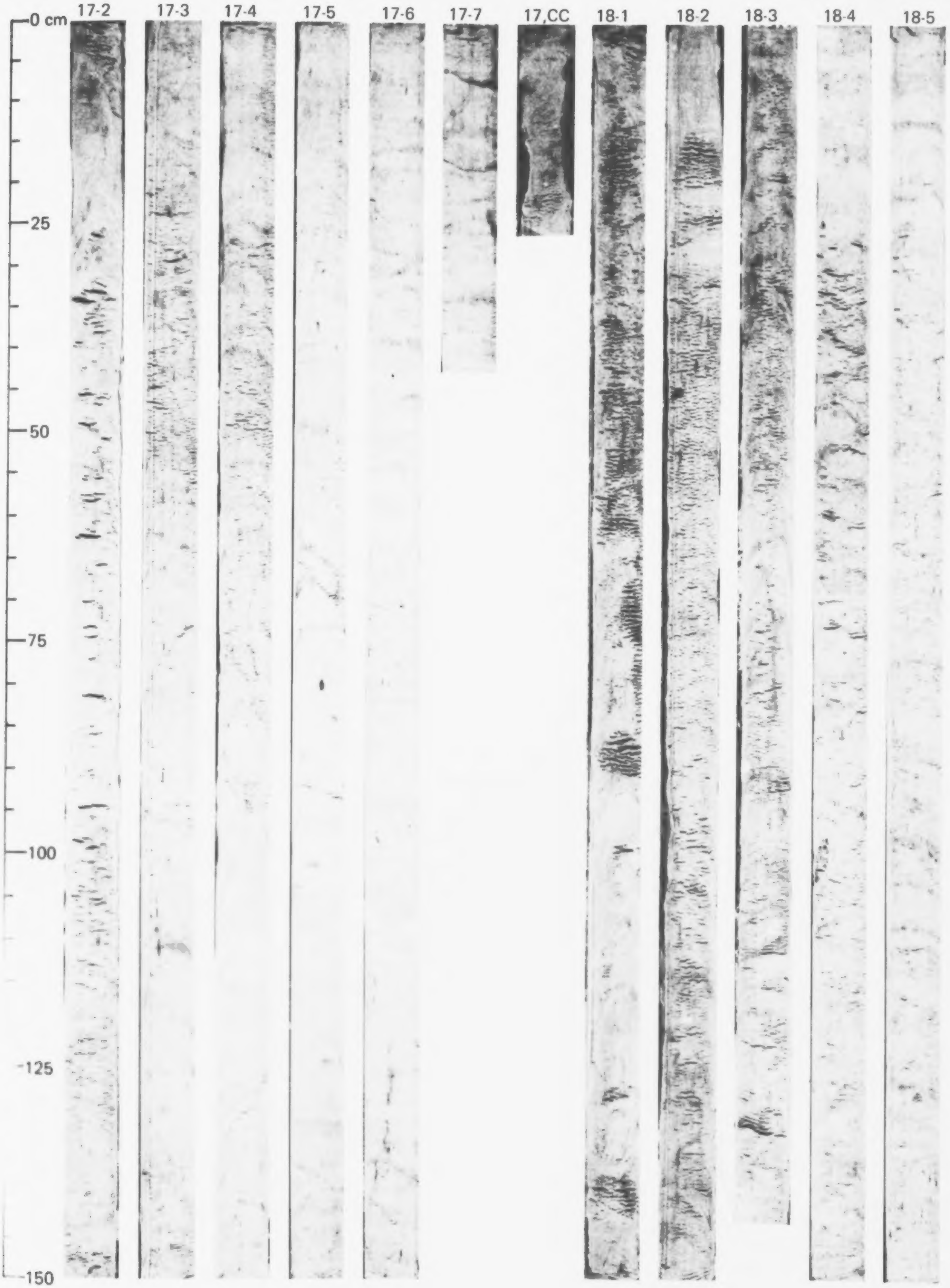

9-5
9-6
9-7
9,CC
10-1
10-2
10-3
10-4
10-5
10-6
10-7
10,CC
0 cm
25
50
75
100
125
150

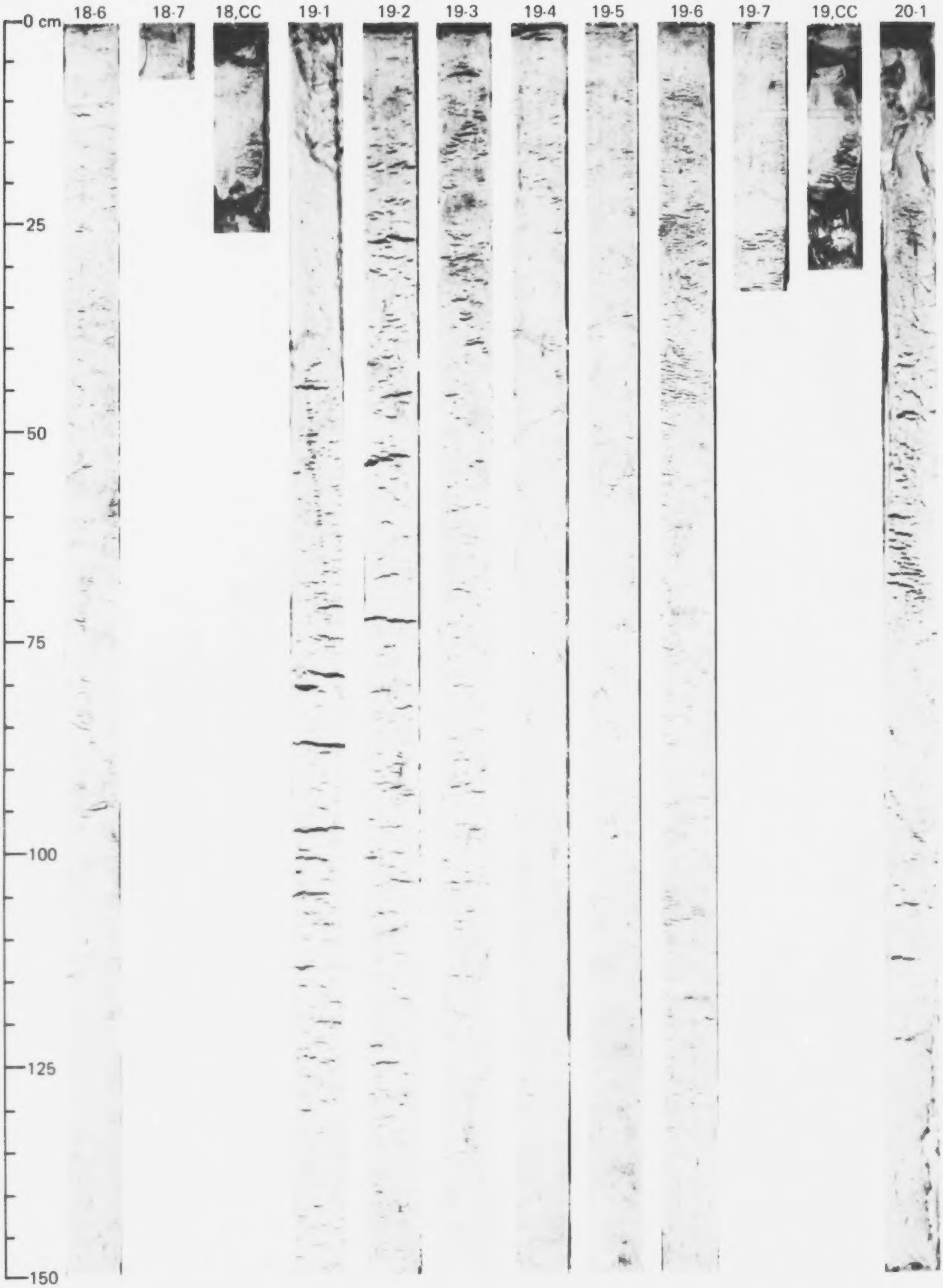

11-1
11-2
11-3
11-4
11-5
11-6
11,CC
12-1
12-2
12-3
12-4
12-5
0 cm
25
50
75
100
125
150

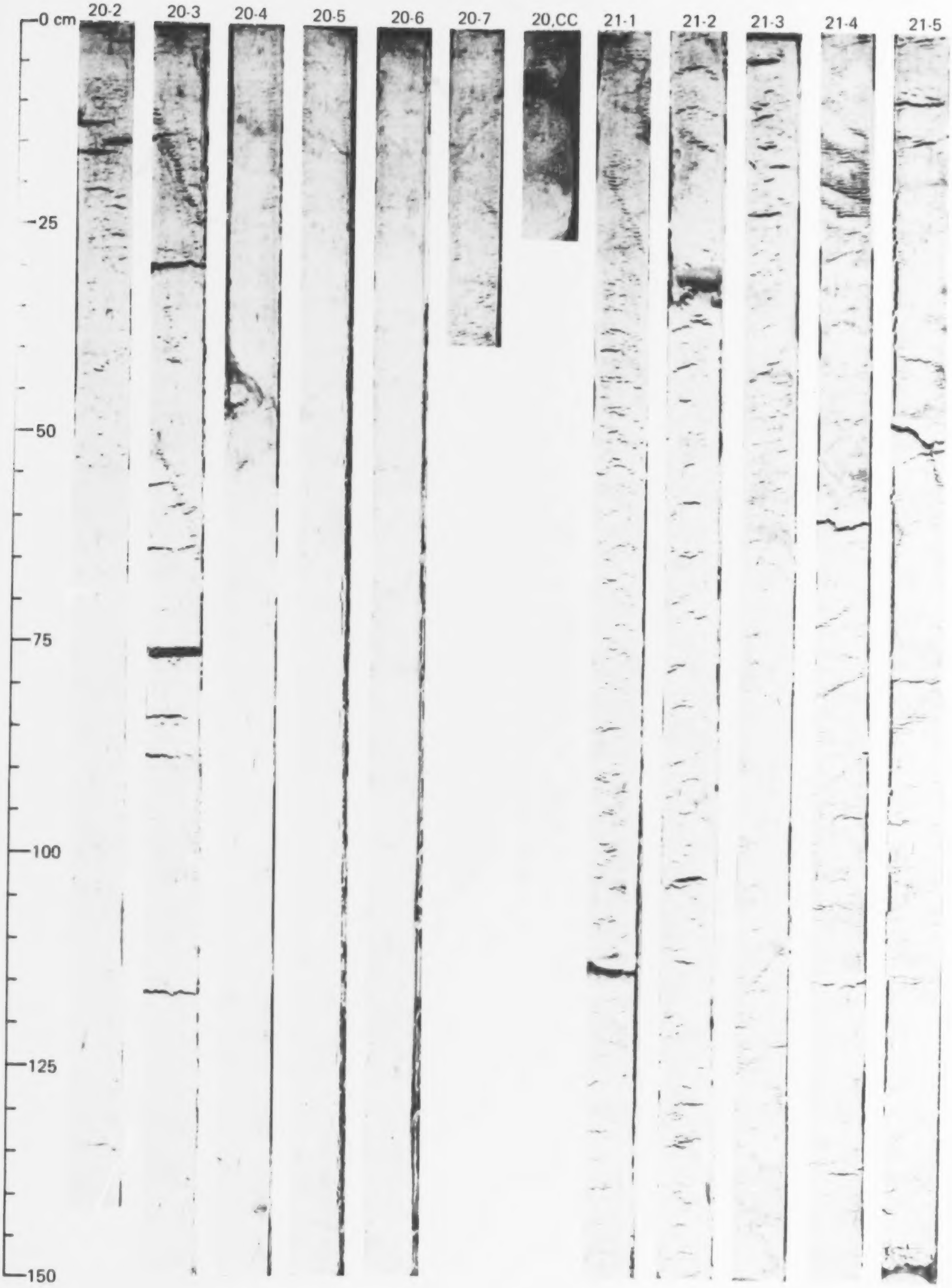

12-6
12-7
12,CC
13-1
13-2
13-3
13-4
13-5
13-6
13-7
13,CC
14-1
0 cm
25
50
75
100
125
150

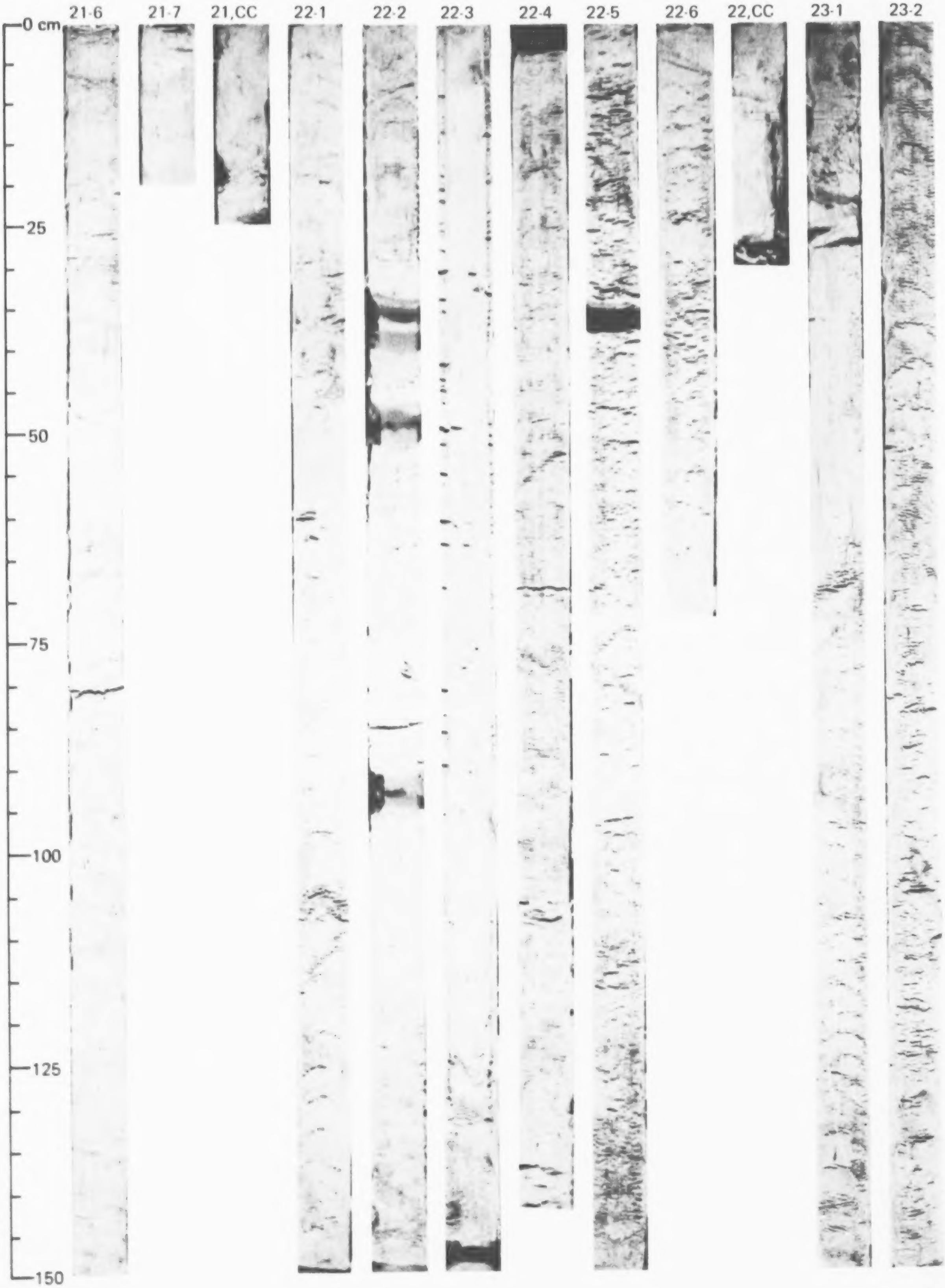

0 cm
25
50
75
100
125
150
14-2
14-3
14-4
14-5
14-6
14-7
14,CC
15-1
15-2
15-3
15-4
15-5

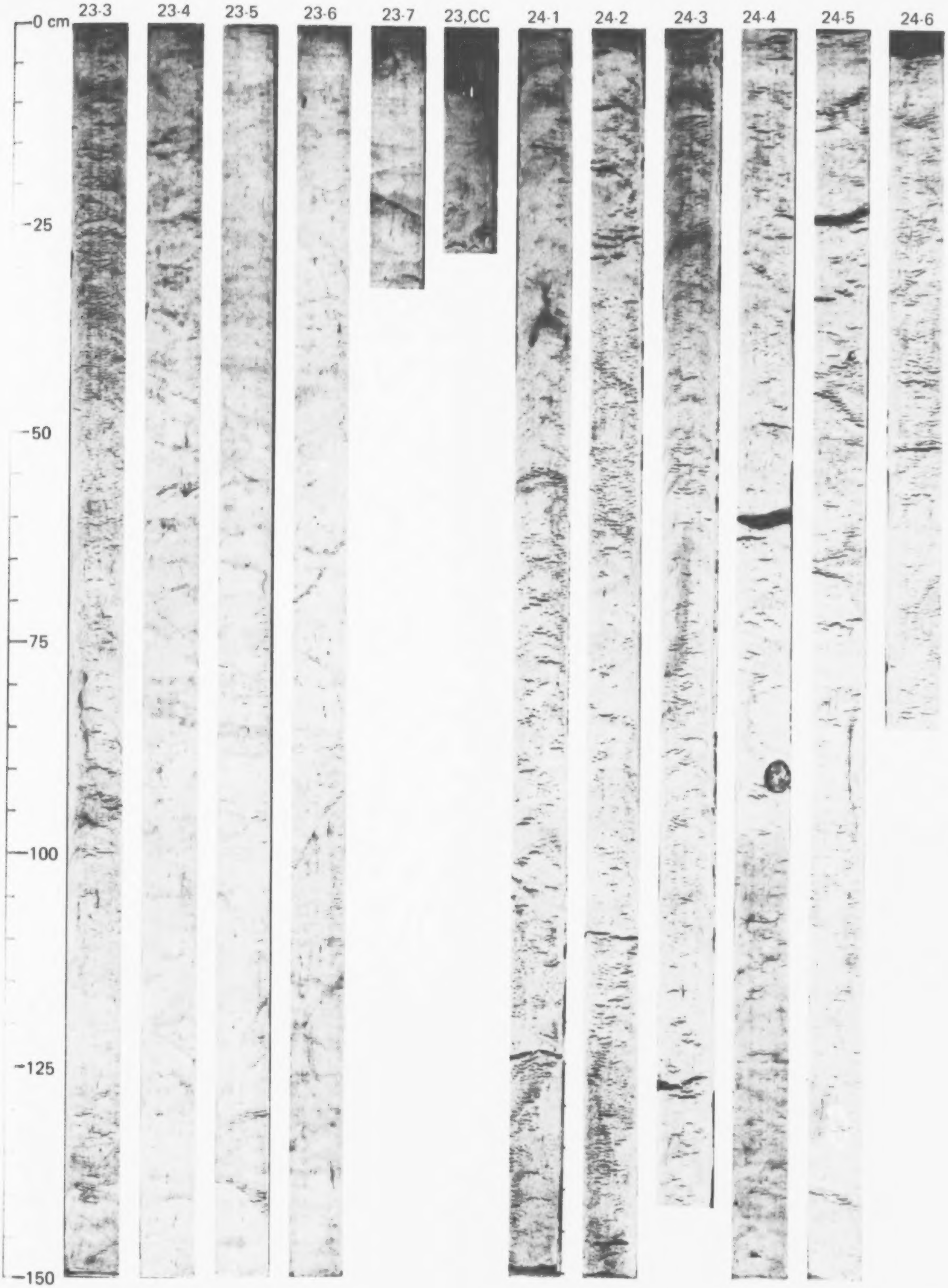

15-6
15-7
15,CC
16-1
16-2
16-3
16-4
16-5
16-6
16-7
16,CC
17-1
0 cm
25
50
75
100
125
150

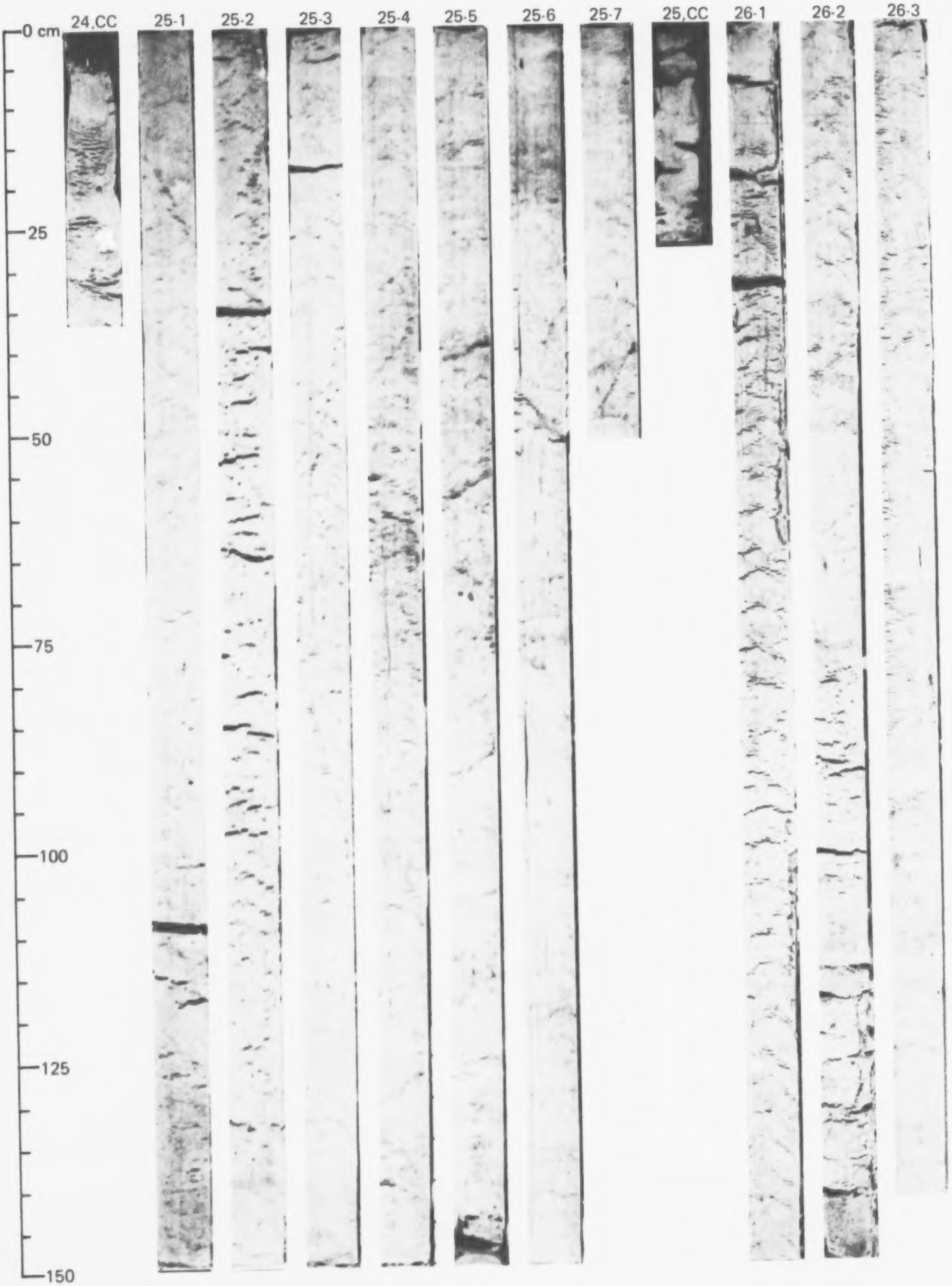

0 cm
25
50
75
100
125
150
17-2
17-3
17-4
17-5
17-6
17-7
17,CC
18-1
18-2
18-3
18-4
18-5


18-6
18-7
18,CC
19-1
19-2
19-3
19-4
19-5
19-6
19-7
19,CC
20-1
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
20-2
20-3
20-4
20-5
20-6
20-7
20,CC
21-1
21-2
21-3
21-4
21-5

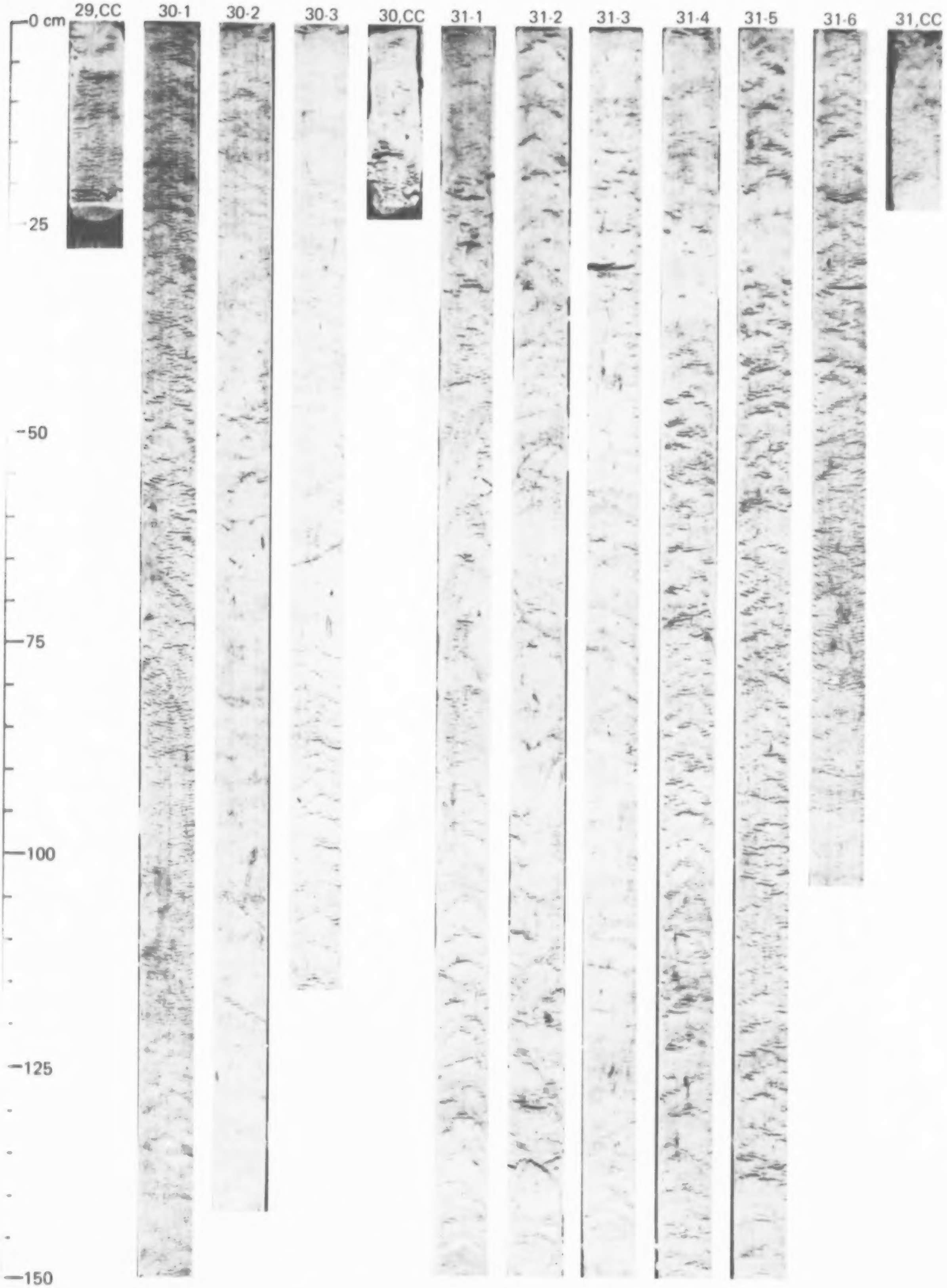

21-6
21-7
21,CC
22-1
22-2
22-3
22-4
22-5
22-6
22,CC
23-1
23-2
0 cm
25
50
75
100
125
150


23-3
23-4
23-5
23-6
23-7
23,CC
24-1
24-2
24-3
24-4
24-5
24-6
0 cm
25
50
75
100
125
150

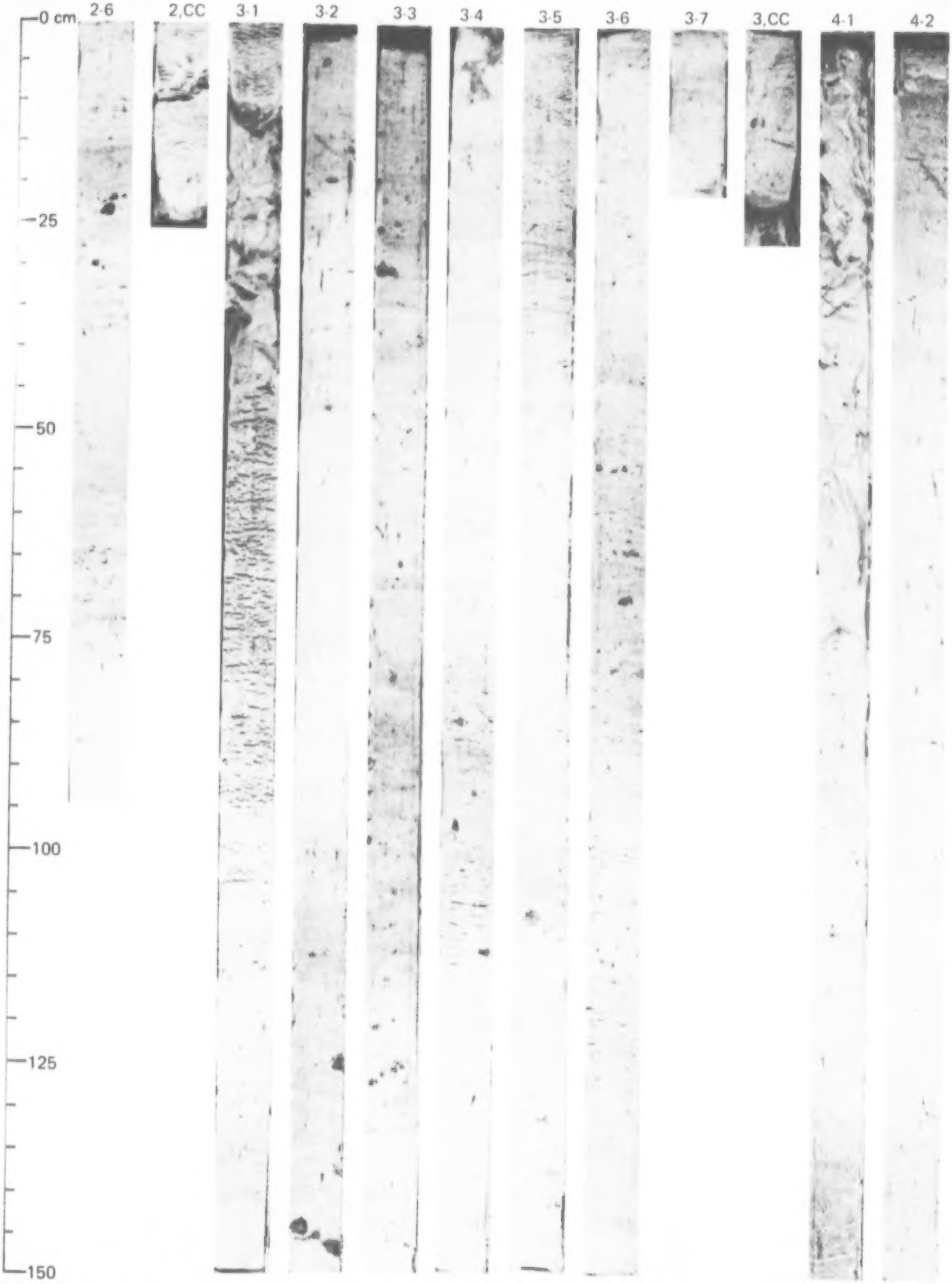

24,CC
25-1
25-2
25-3
25-4
25-5
25-6
25-7
25,CC
26-1
26-2
26-3
0 cm
25
50
75
100
125
150

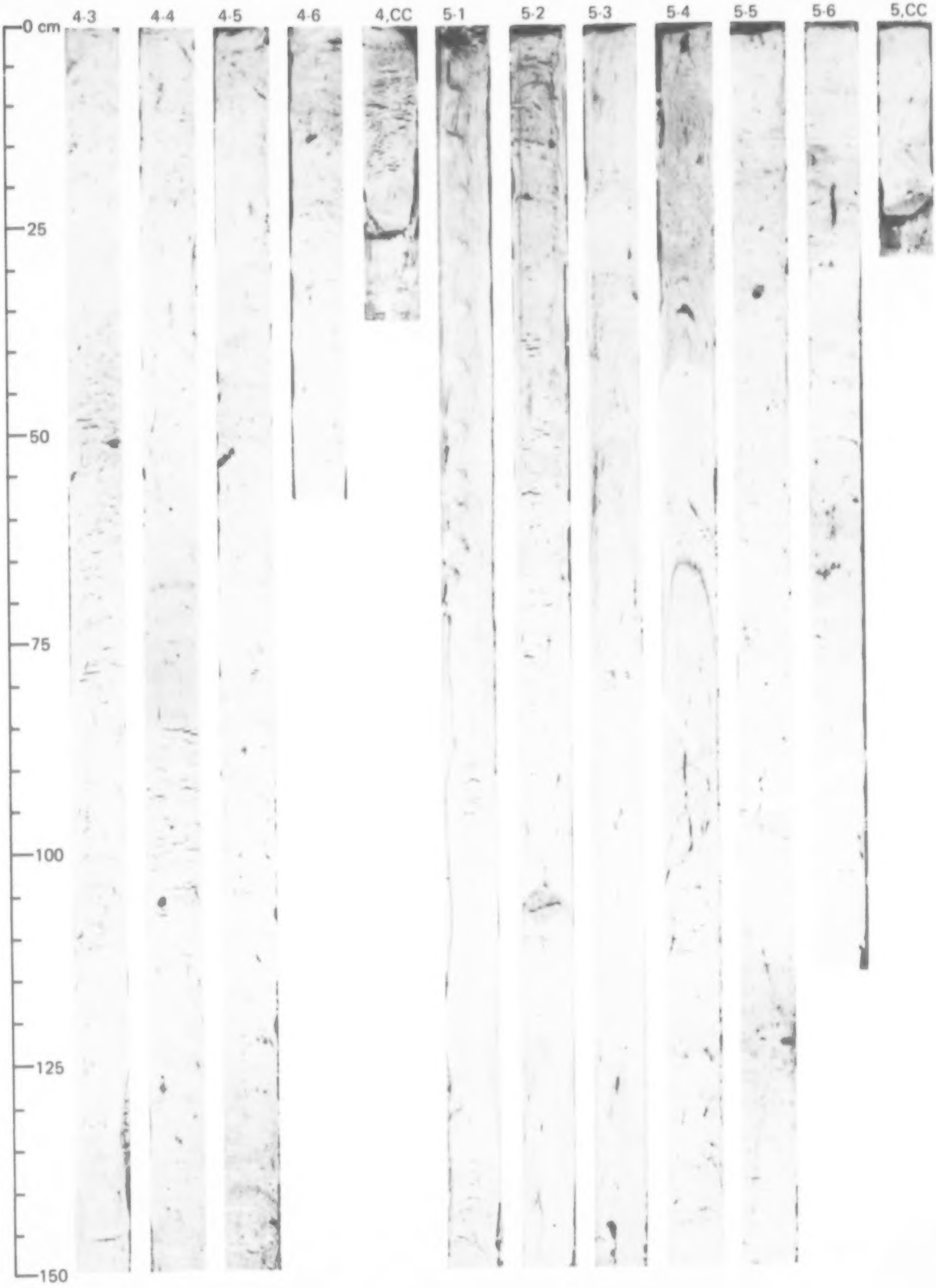
0 cm
25
50
75
100
125
150
26-4
26-5
26,CC
27-1
27-2
27-3
27-4
27-5
27-6
27-7
27,CC
28-1

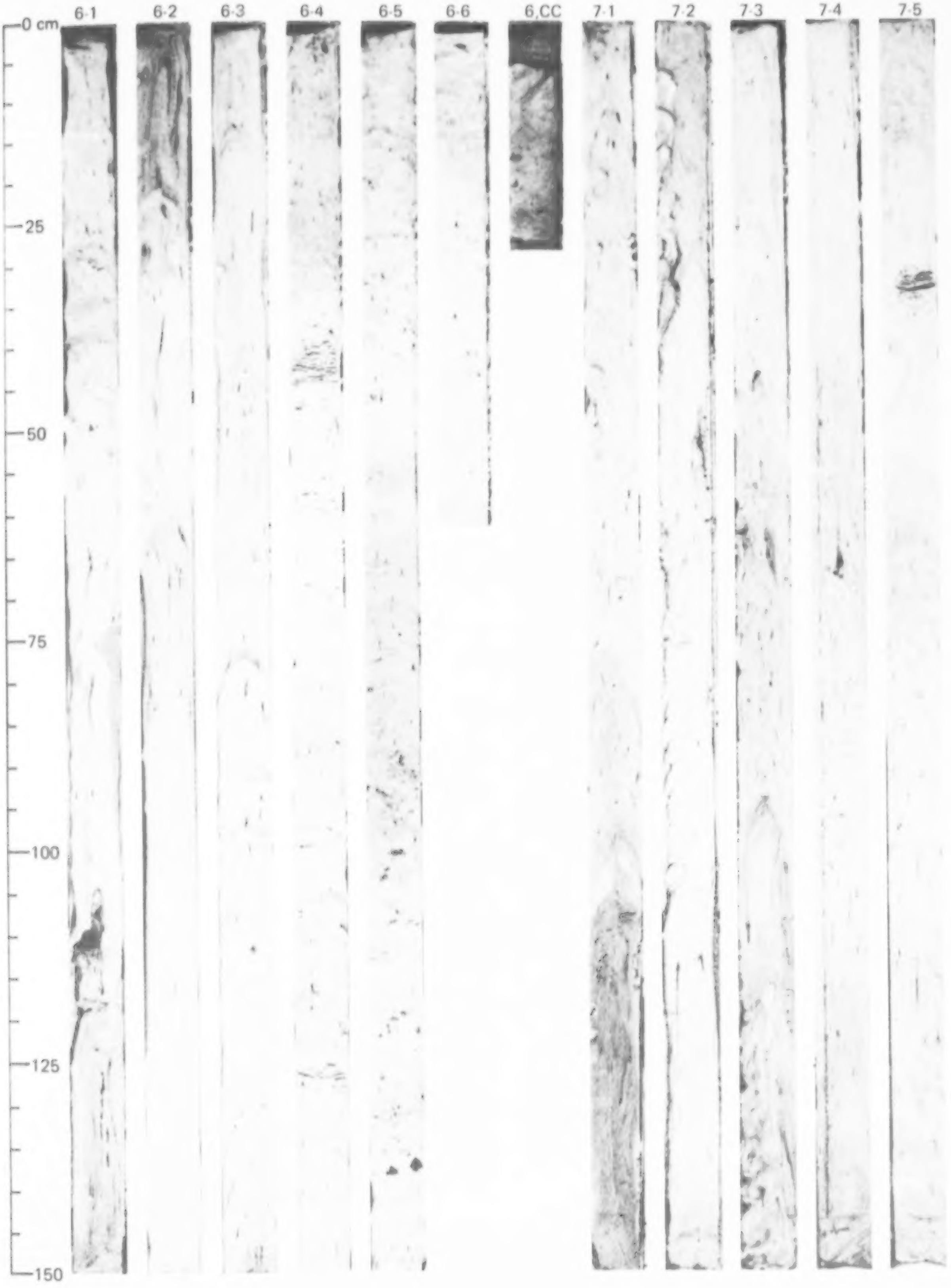
0 cm
25
50
75
100
125
150
28-2
28-3
28-4
28-5
28-6
28,CC
29-1
29-2
29-3
29-4
29-5
29-6


0 cm
25
50
75
100
125
150
29,CC
30-1
30-2
30-3
30,CC
31-1
31-2
31-3
31-4
31-5
31-6
31,CC

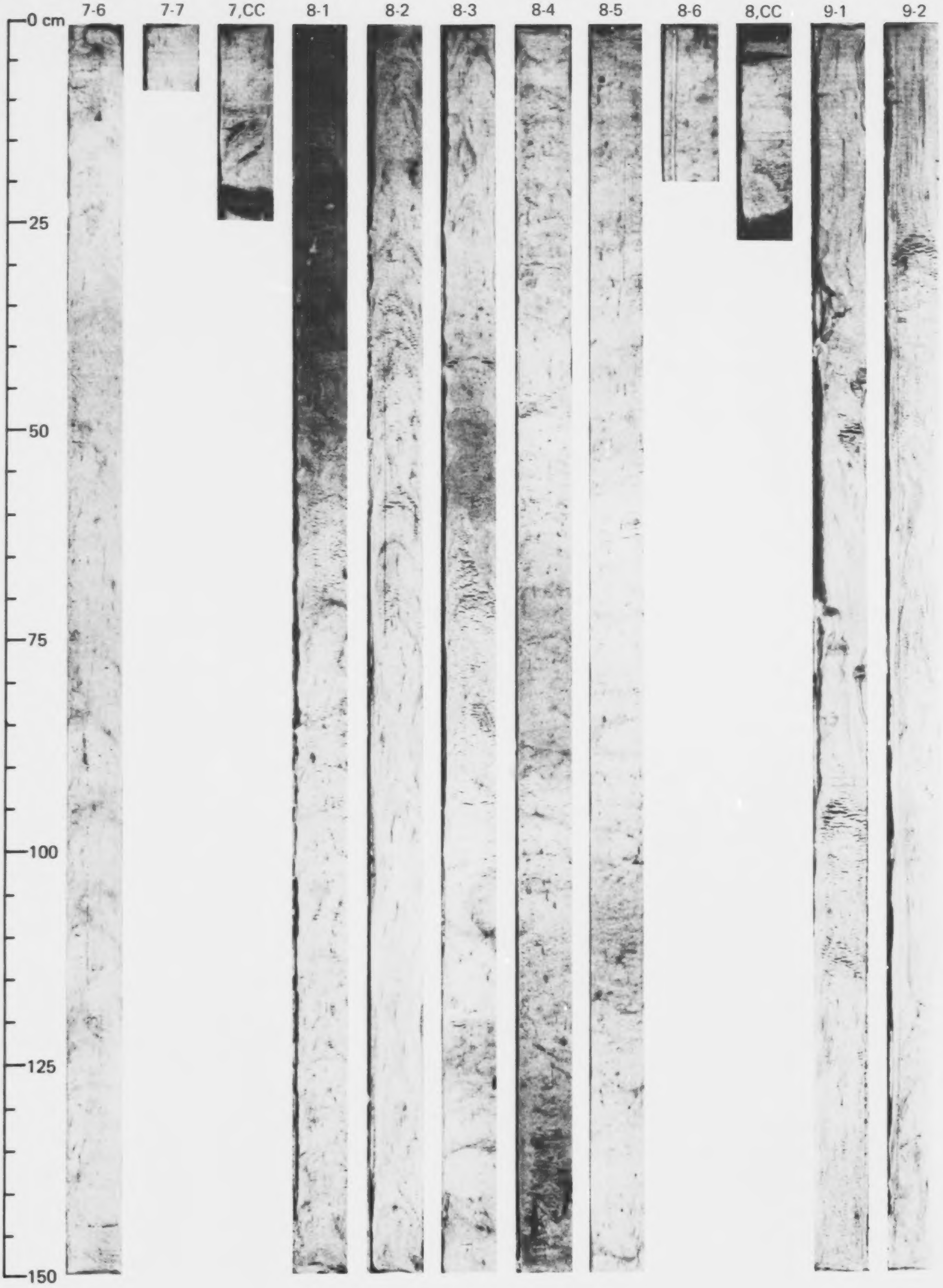
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1,CC
2-1
2-2
2-3
2-4
2-5


0 cm
25
50
75
100
125
150
2-6
2,CC
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3,CC
4-1
4-2


0 cm
25
50
75
100
125
150
4-3
4-4
4-5
4-6
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5,CC

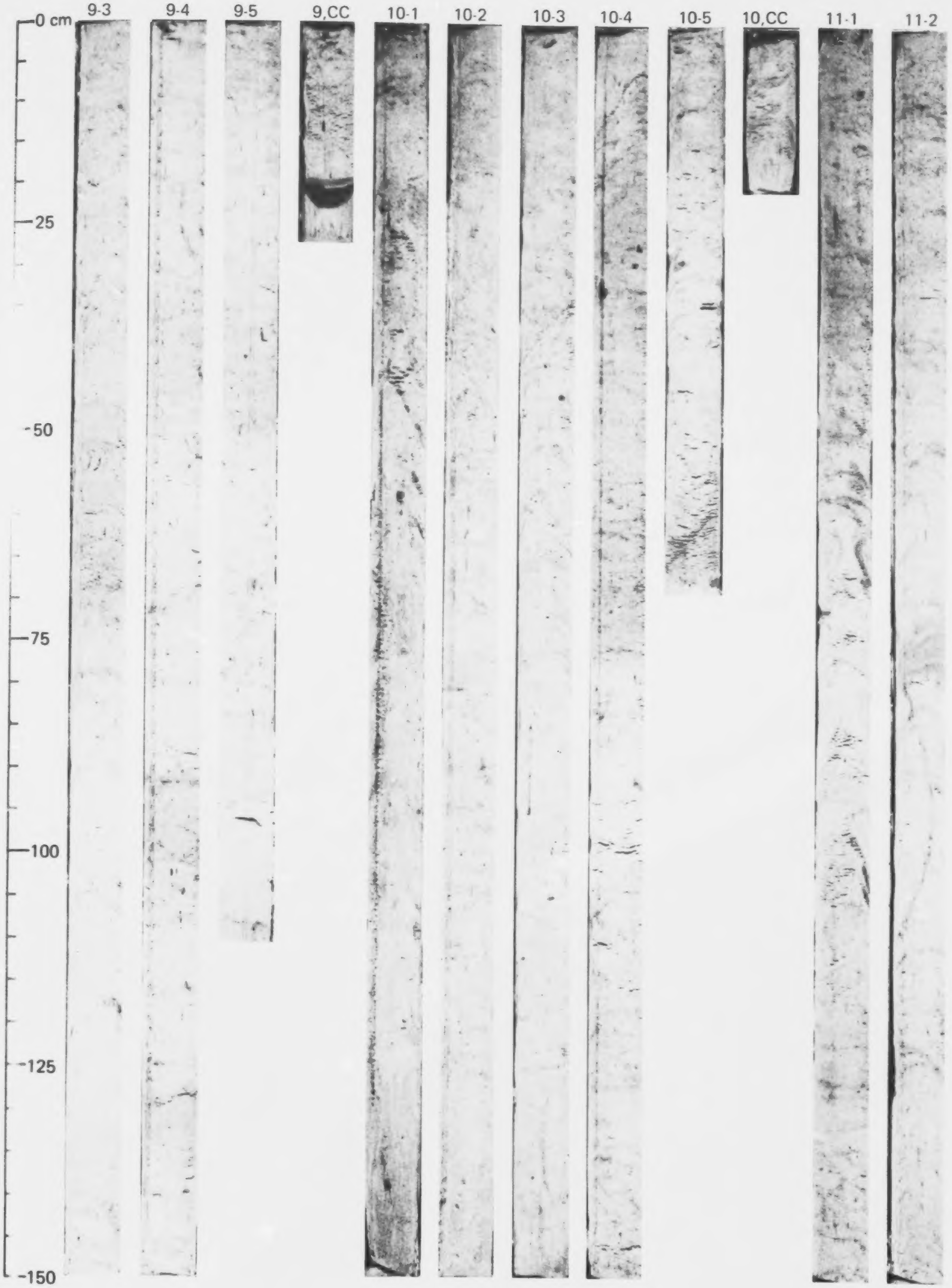

6-1
6-2
6-3
6-4
6-5
6-6
6,CC
7-1
7-2
7-3
7-4
7-5
0 cm
25
50
75
100
125
150

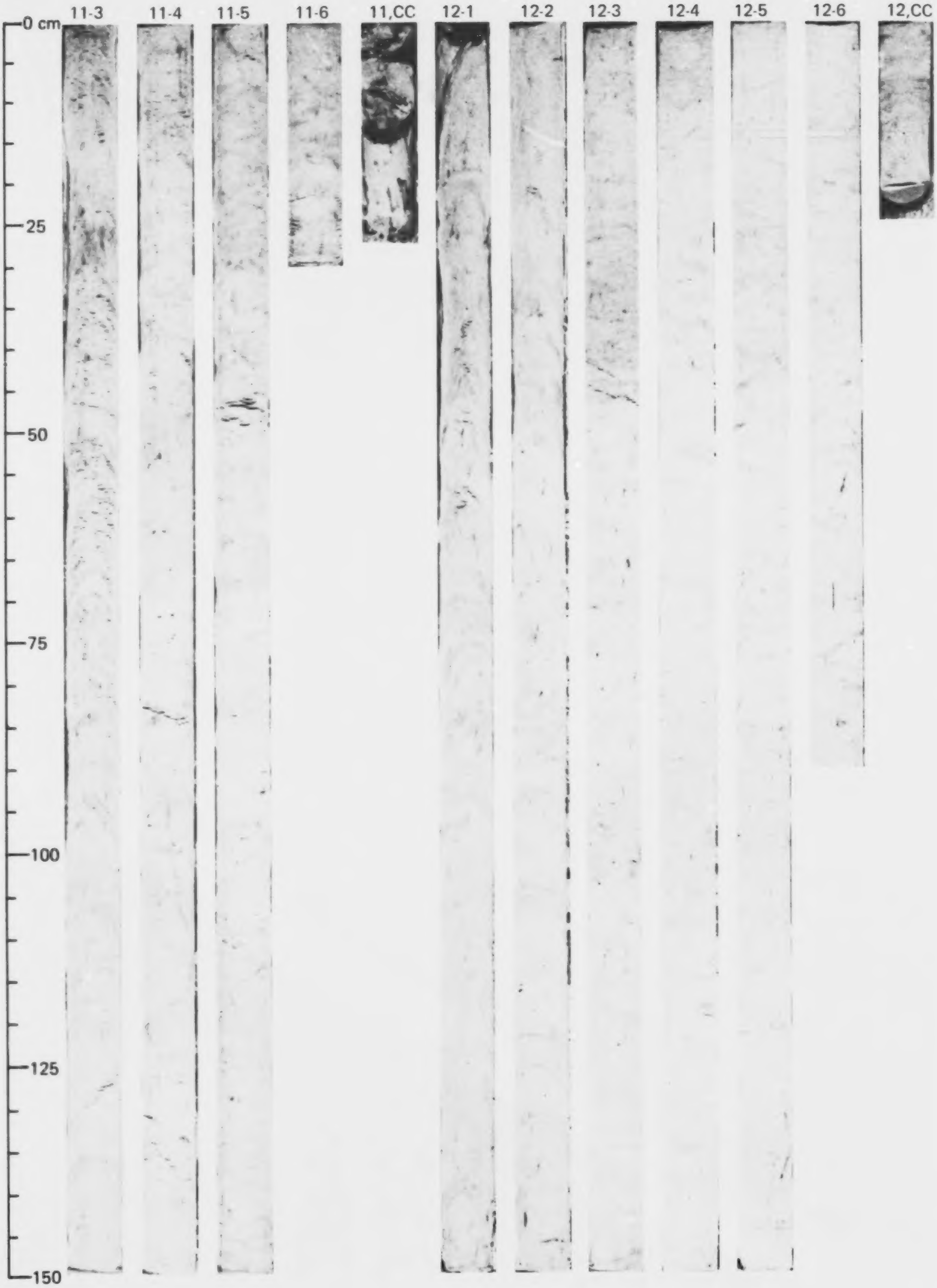
SITE 591 (HOLE 591A)

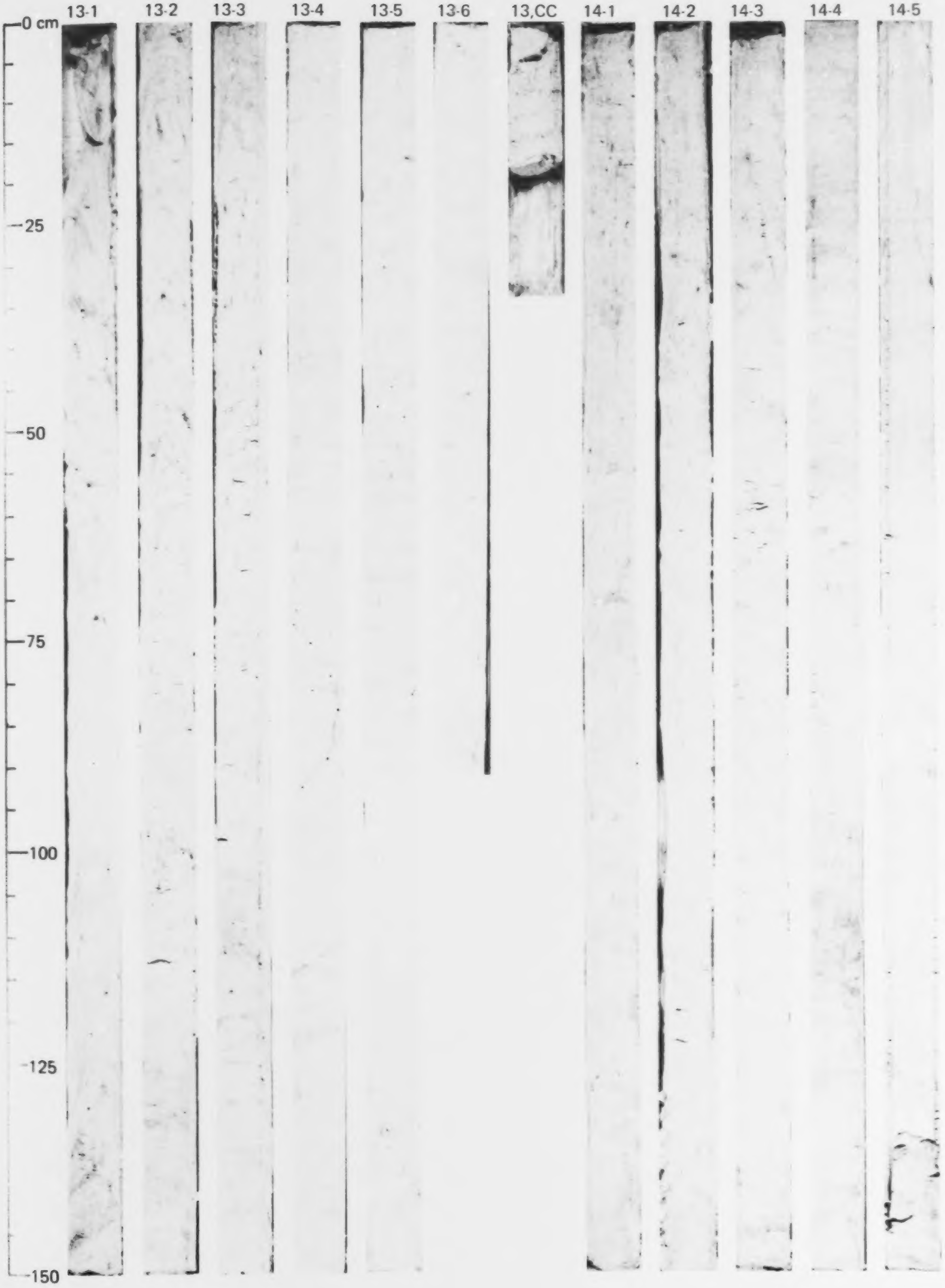


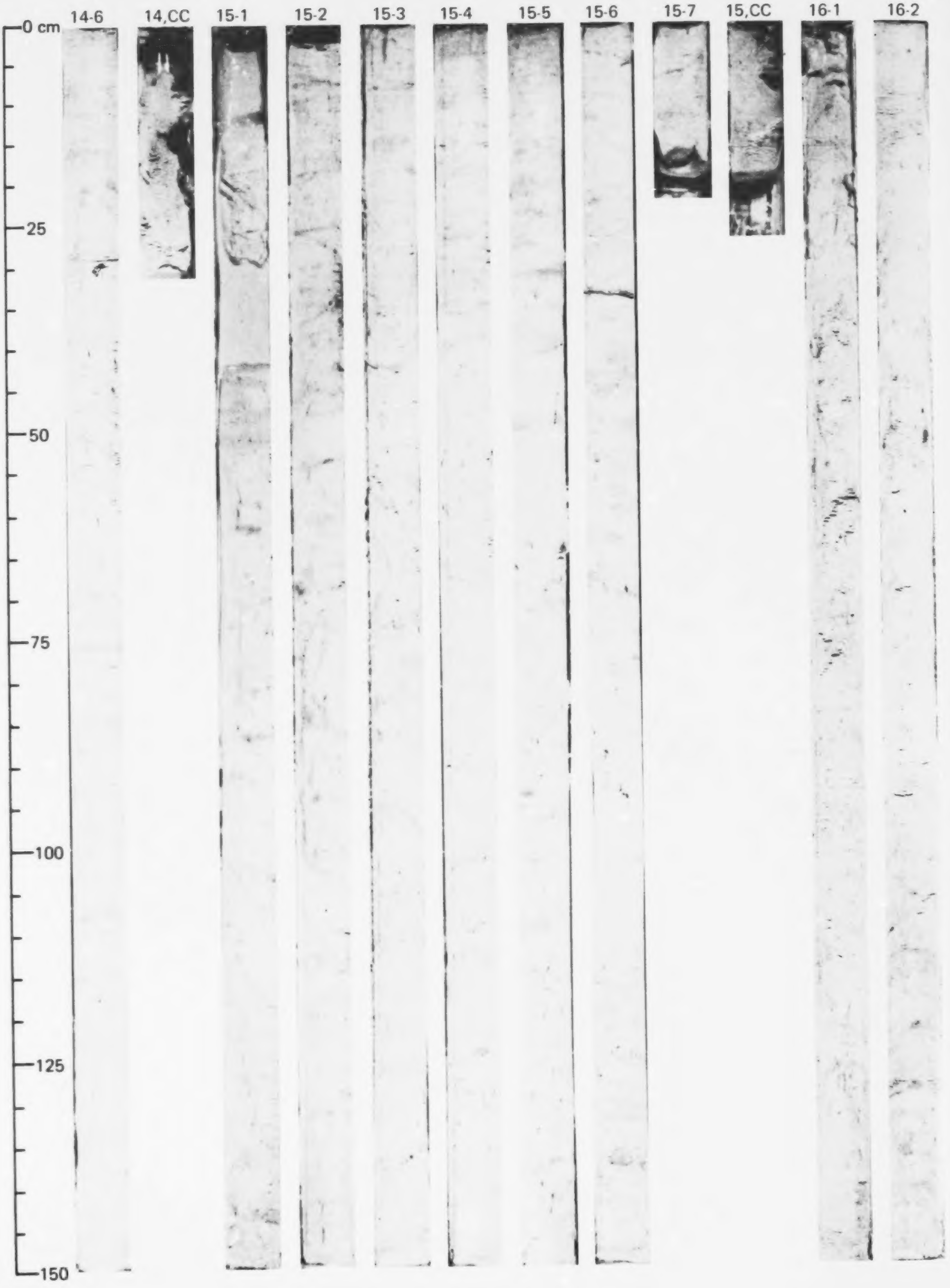
7-6
7-7
7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8,CC
9-1
9-2
0 cm
25
50
75
100
125
150

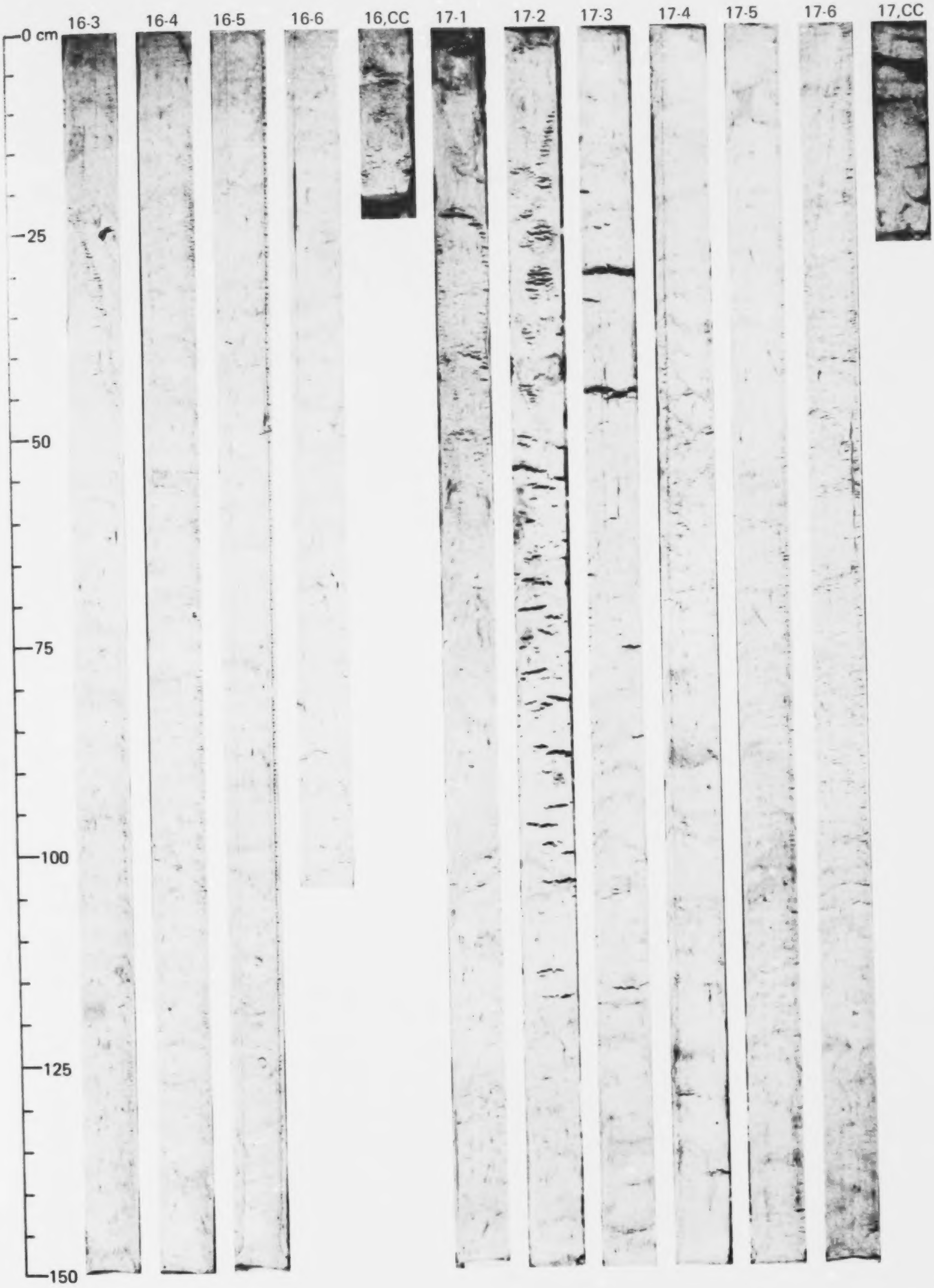
READEX FICHE best copy available

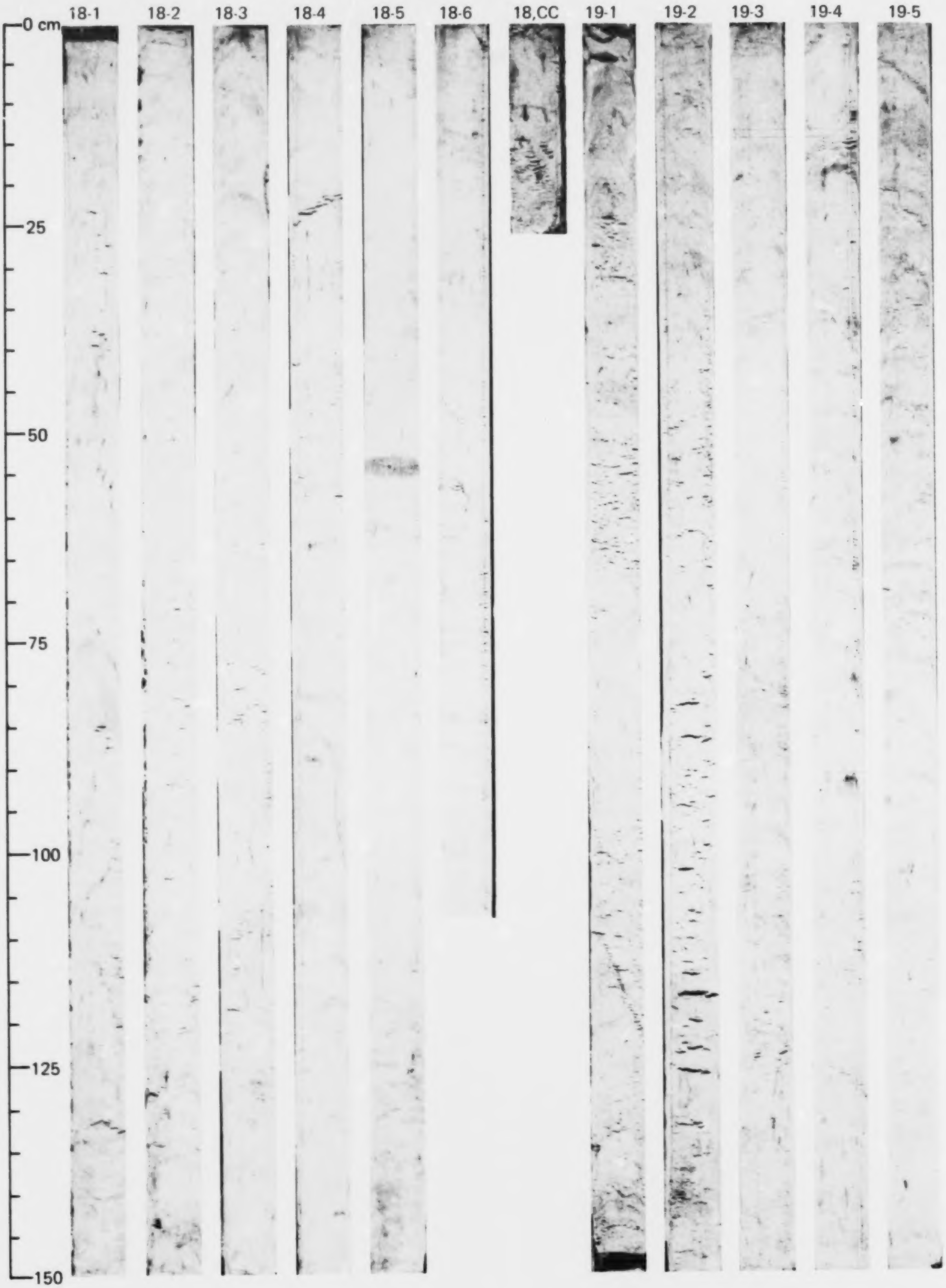

9-3
9-4
9-5
9,CC
10-1
10-2
10-3
10-4
10-5
10,CC
11-1
11-2
0 cm
25
50
75
100
125
150

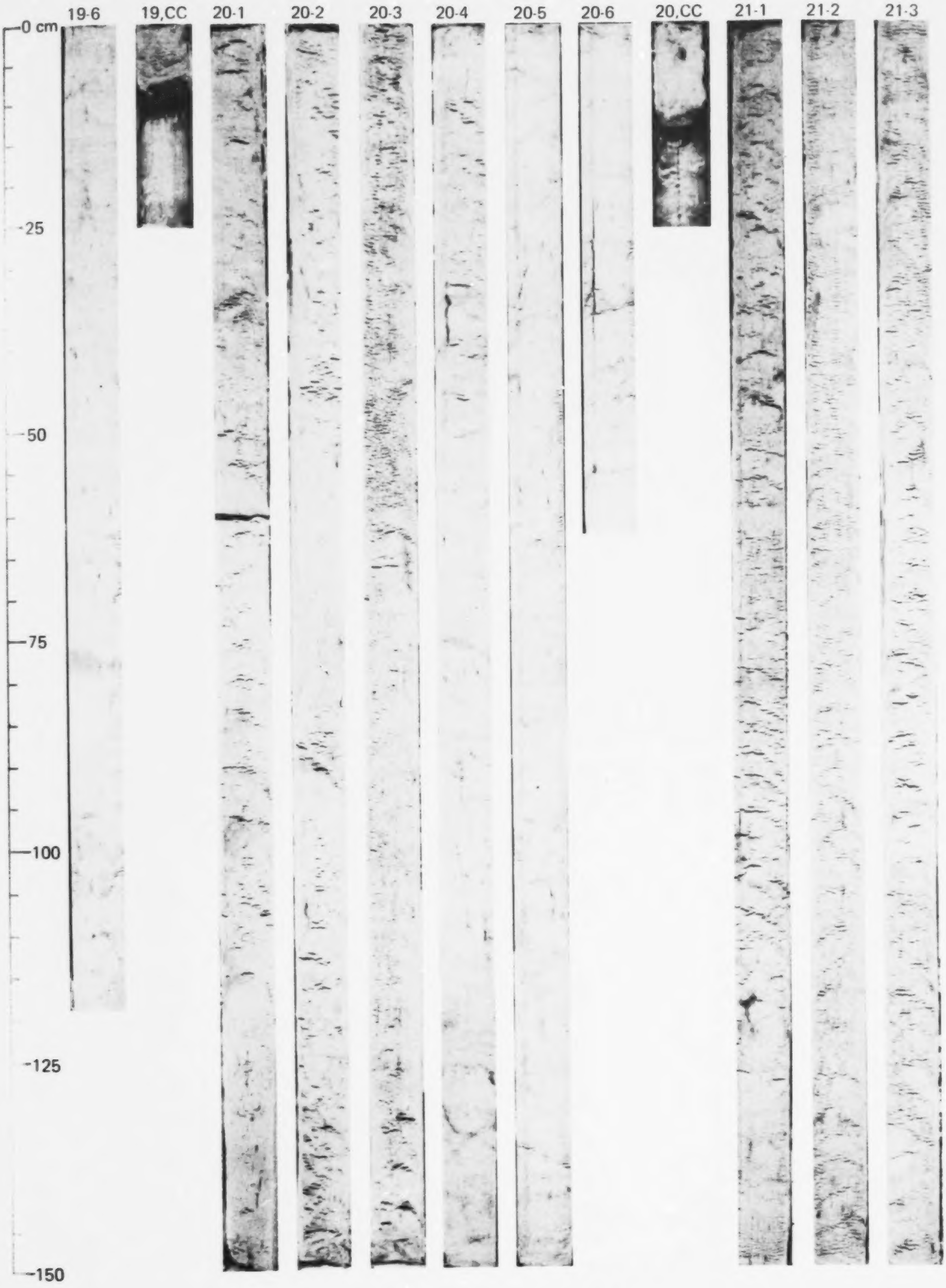

11-3
11-4
11-5
11-6
11,CC
12-1
12-2
12-3
12-4
12-5
12-6
12,CC
0 cm
25
50
75
100
125
150

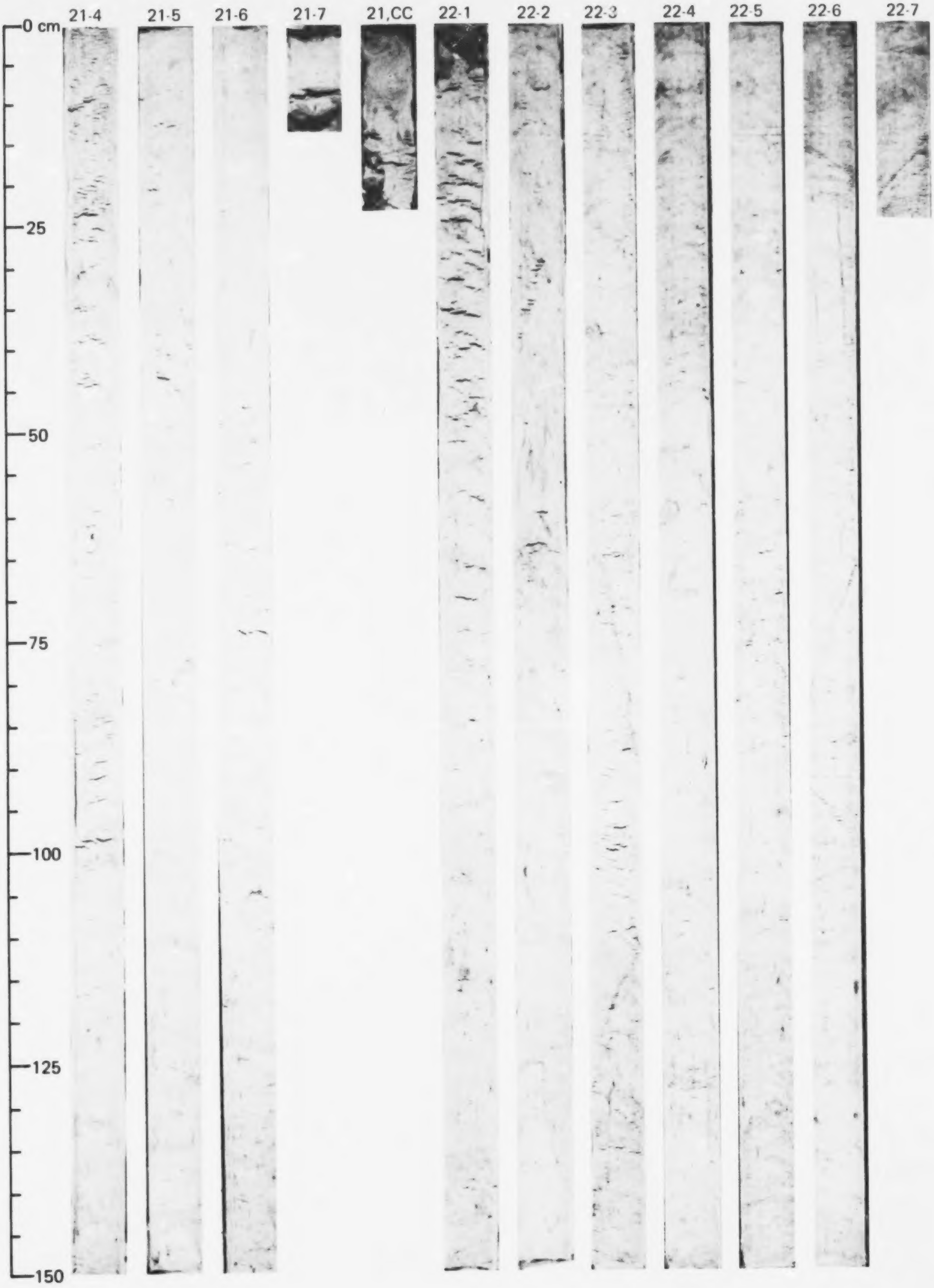

13-1
13-2
13-3
13-4
13-5
13-6
13,CC
14-1
14-2
14-3
14-4
14-5
0 cm
25
50
75
100
125
150

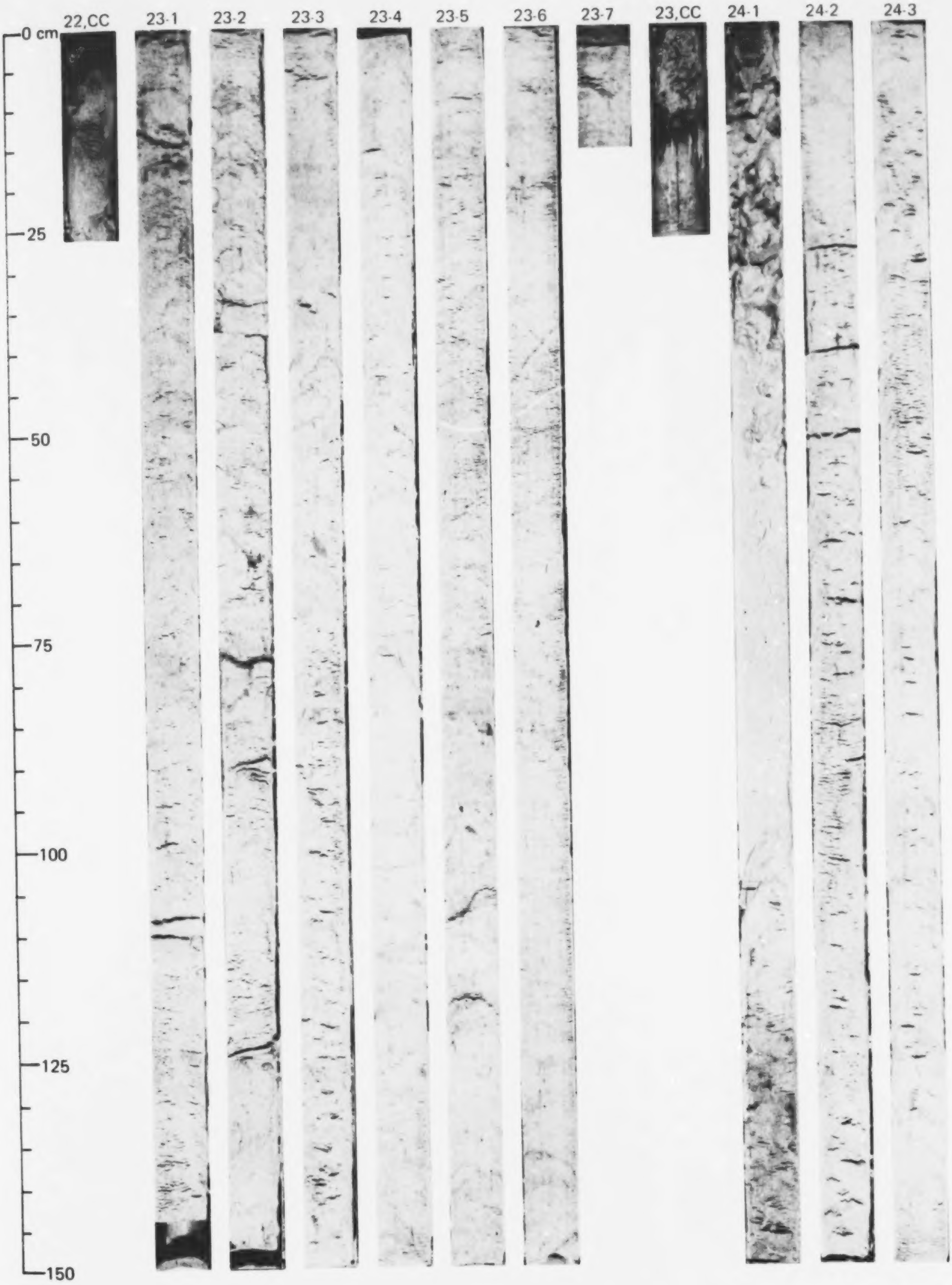

14-6
14,CC
15-1
15-2
15-3
15-4
15-5
15-6
15-7
15,CC
16-1
16-2
0 cm
25
50
75
100
125
150

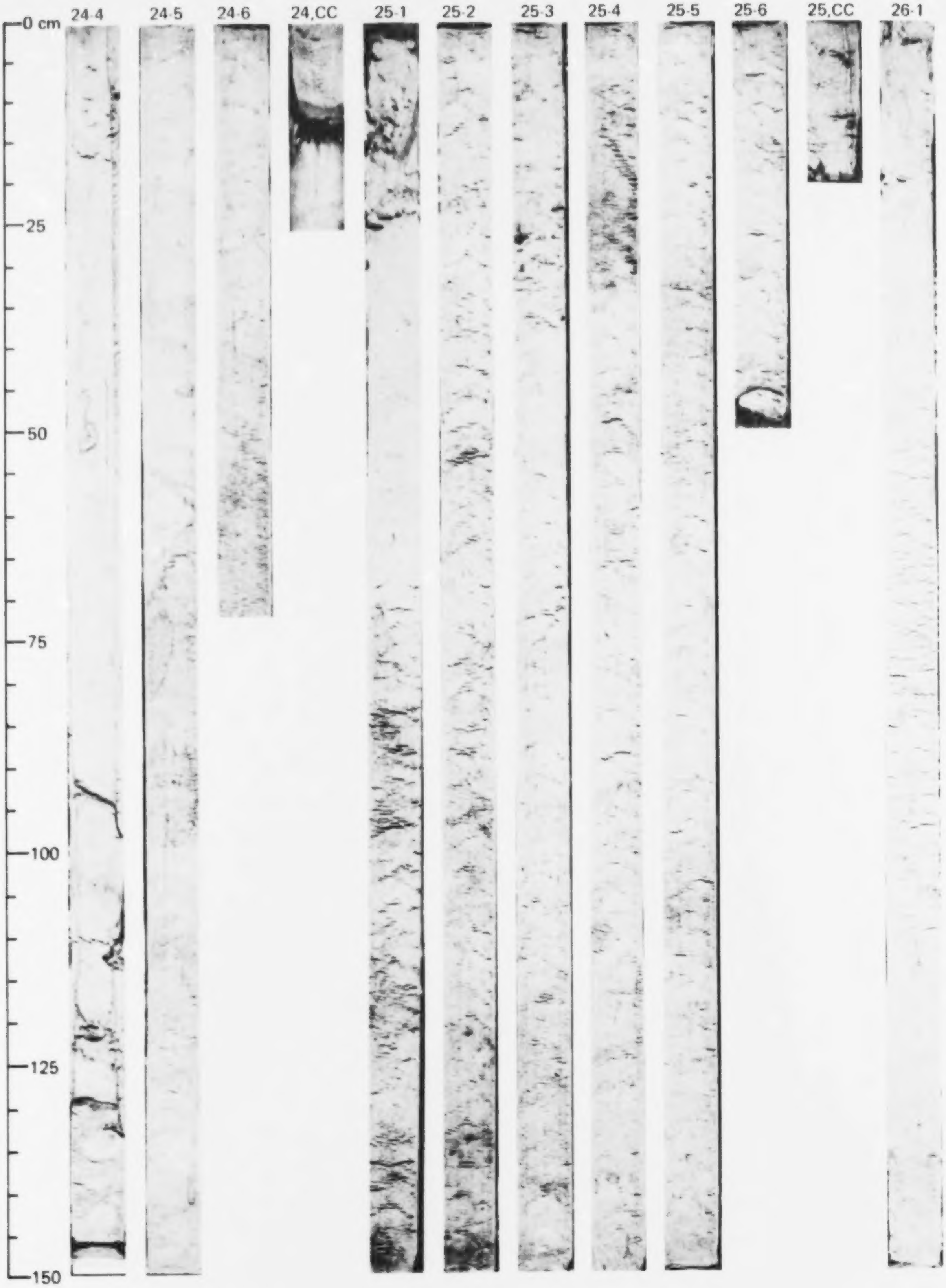

16-3
16-4
16-5
16-6
16,CC
17-1
17-2
17-3
17-4
17-5
17-6
17,CC
0 cm
25
50
75
100
125
150

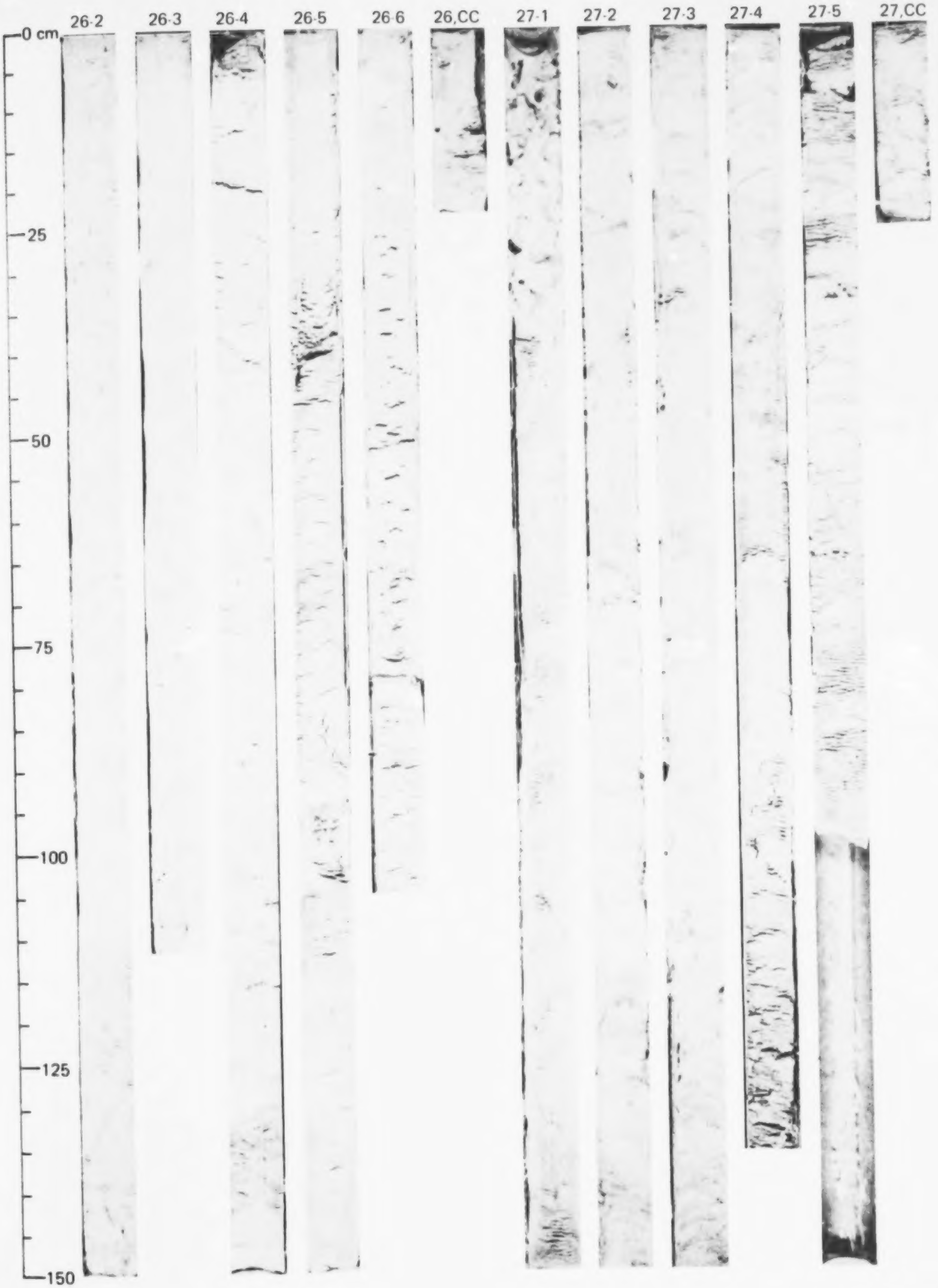

18-1
18-2
18-3
18-4
18-5
18-6
18,CC
19-1
19-2
19-3
19-4
19-5
0 cm
25
50
75
100
125
150

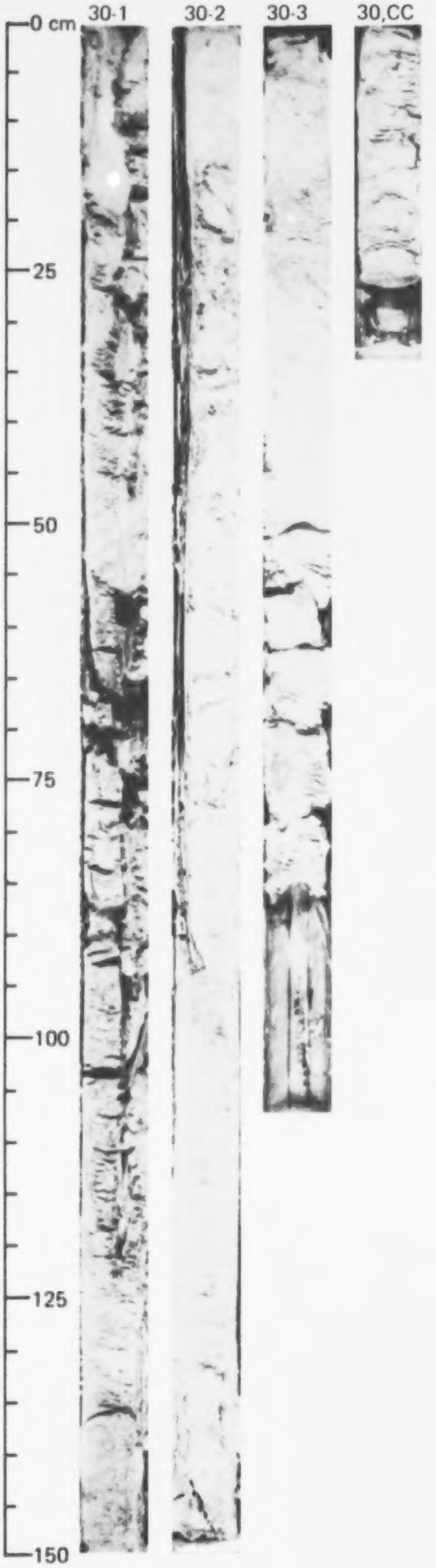

19-6
19,CC
20-1
20-2
20-3
20-4
20-5
20-6
20,CC
21-1
21-2
21-3
0 cm
25
50
75
100
125
150

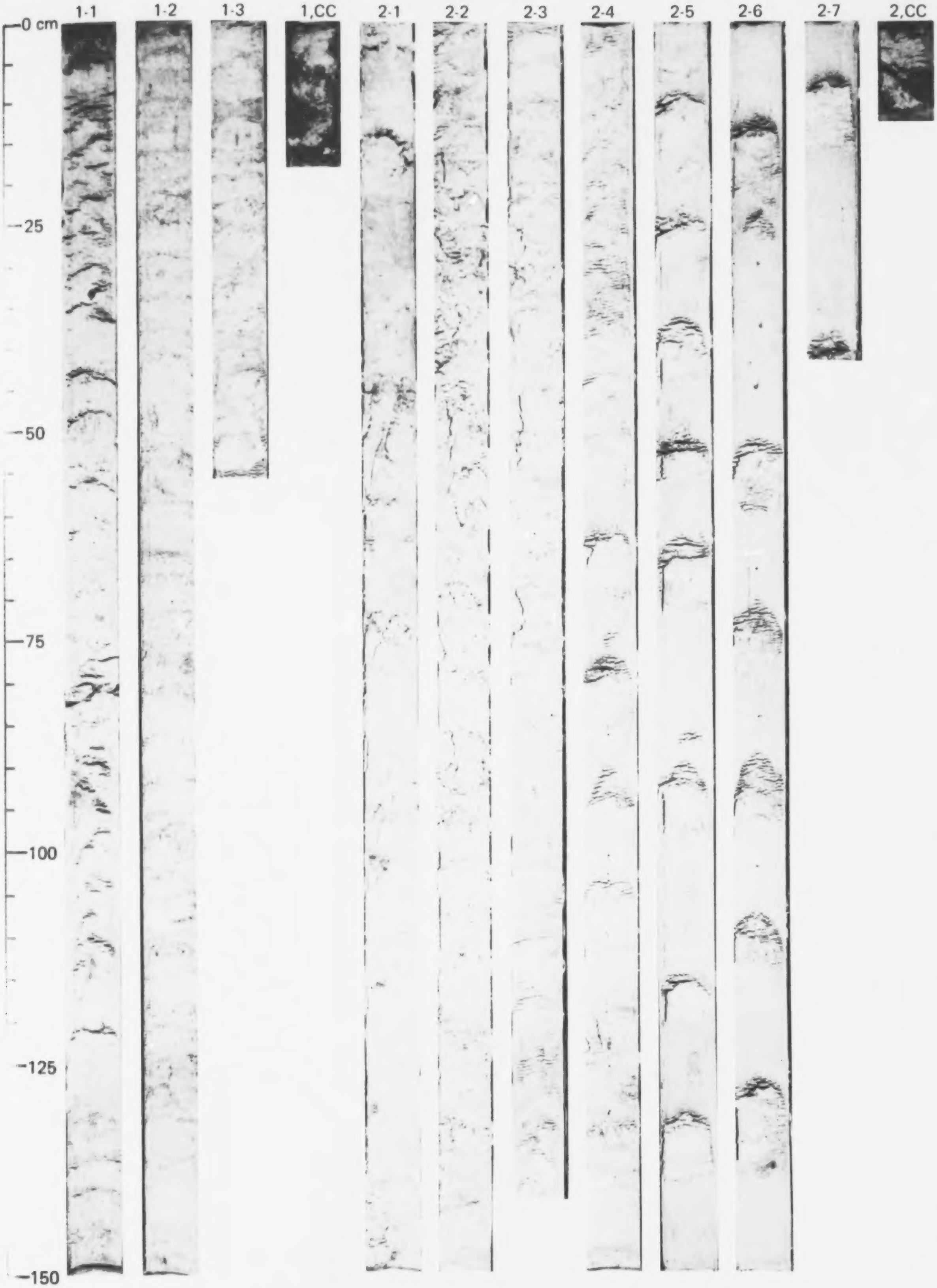

21-4
21-5
21-6
21-7
21,CC
22-1
22-2
22-3
22-4
22-5
22-6
22-7
0 cm
25
50
75
100
125
150


22,CC
23-1
23-2
23-3
23-4
23-5
23-6
23-7
23,CC
24-1
24-2
24-3
0 cm
25
50
75
100
125
150

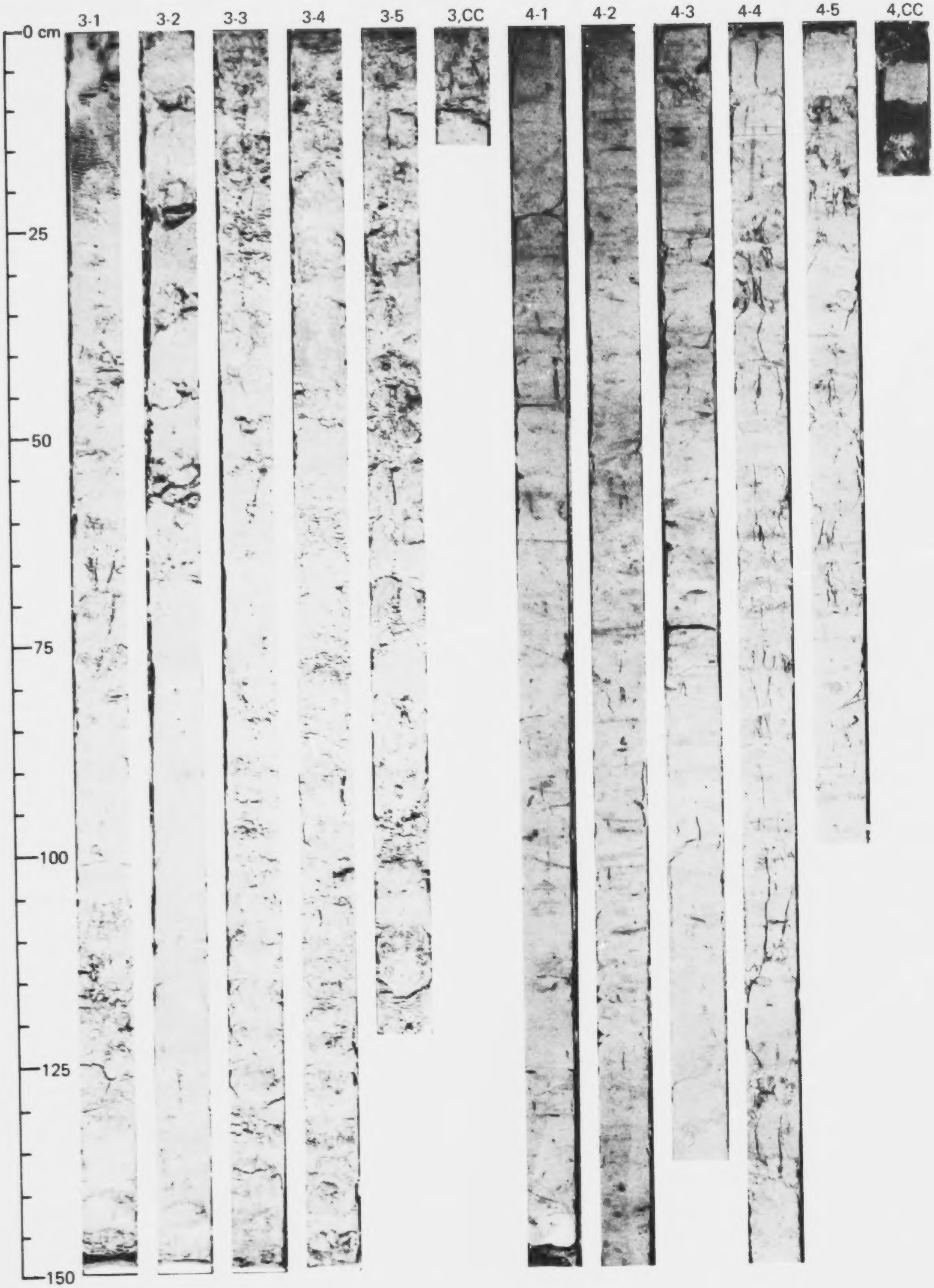

0 cm
25
50
75
100
125
150
24-4
24-5
24-6
24,CC
25-1
25-2
25-3
25-4
25-5
25-6
25,CC
26-1

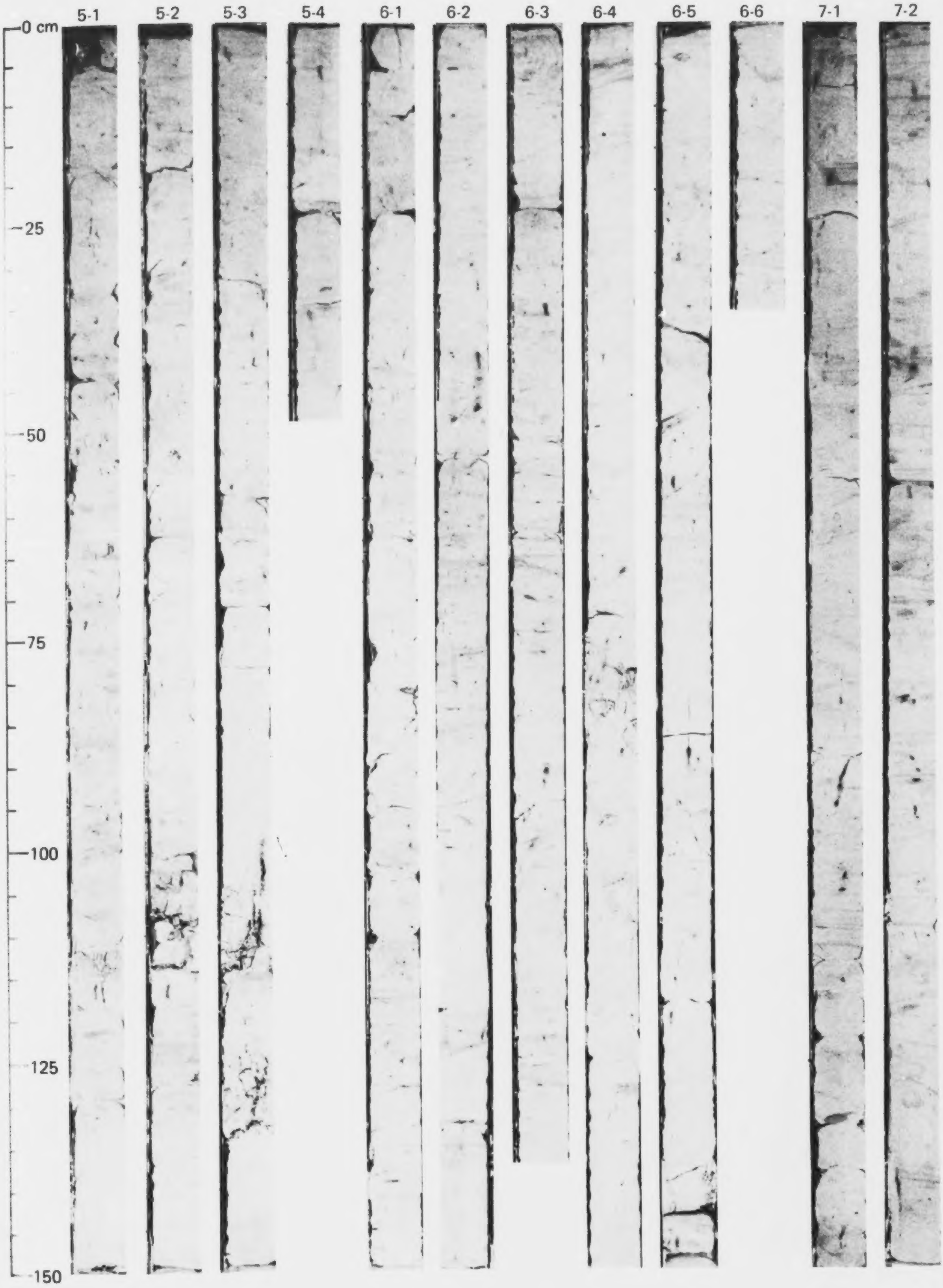

26-2
26-3
26-4
26-5
26-6
26,CC
27-1
27-2
27-3
27-4
27-5
27,CC
0 cm
25
50
75
100
125
150

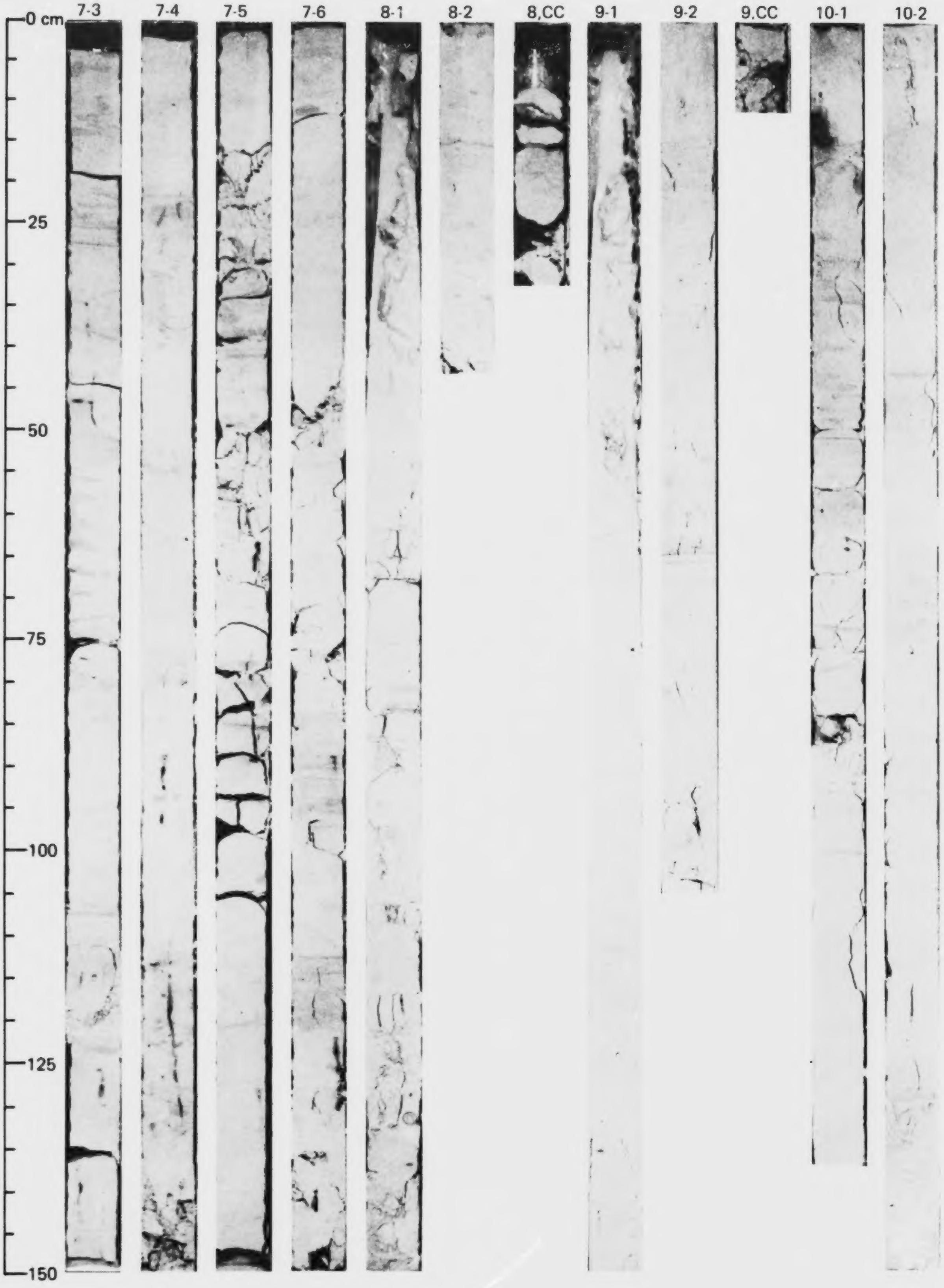

0 cm
25
50
75
100
125
150
30-1
30-2
30-3
30,CC


1-1
1-2
1-3
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2,CC
0 cm
25
50
75
100
125
150

SITE 591 (HOLE 591B)


3-1
3-2
3-3
3-4
3-5
3,CC
4-1
4-2
4-3
4-4
4-5
4,CC
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
5-1
5-2
5-3
5-4
6-1
6-2
6-3
6-4
6-5
6-6
7-1
7-2


0 cm
25
50
75
100
125
150
7-3
7-4
7-5
7-6
8-1
8-2
8,CC
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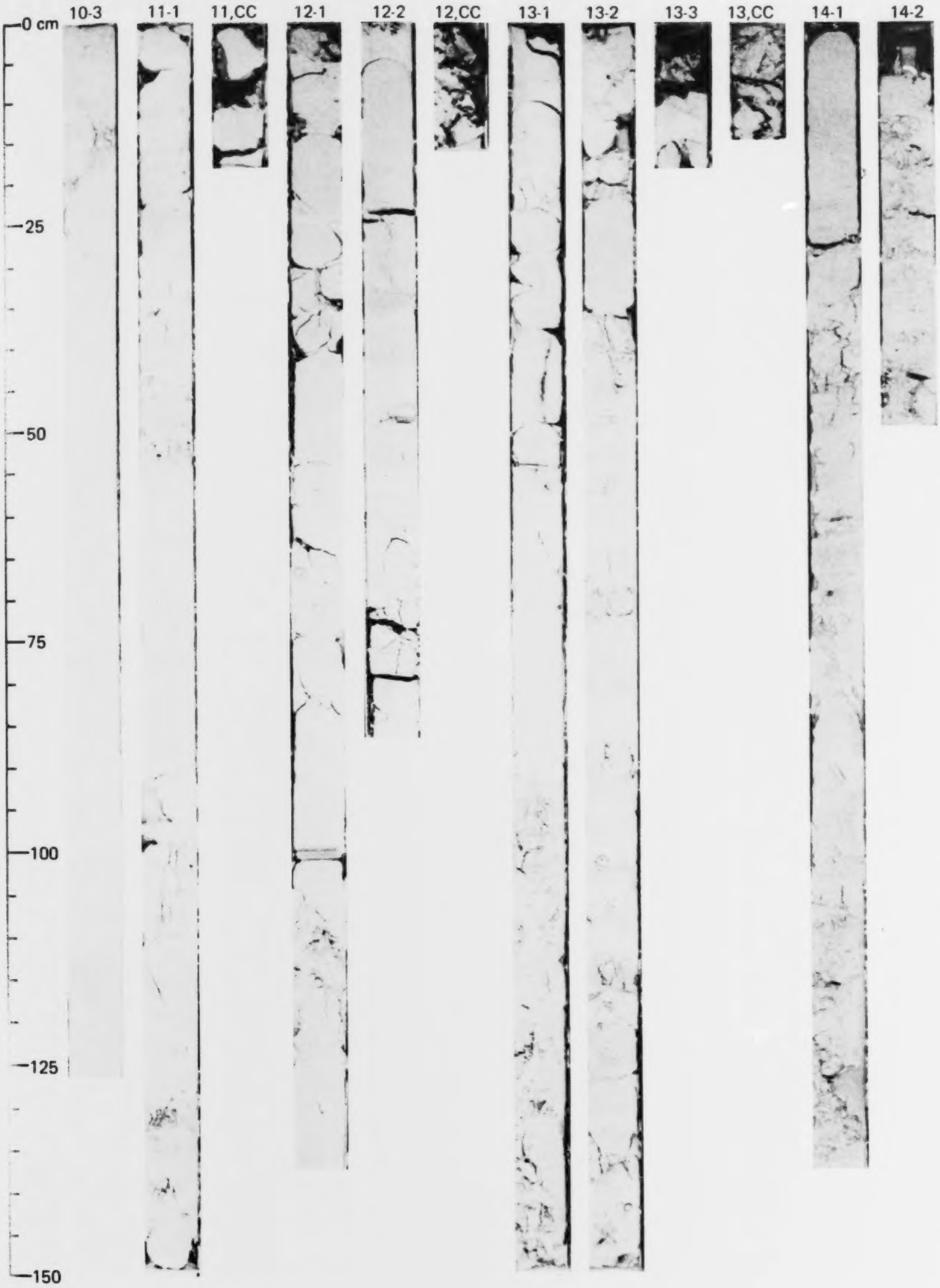
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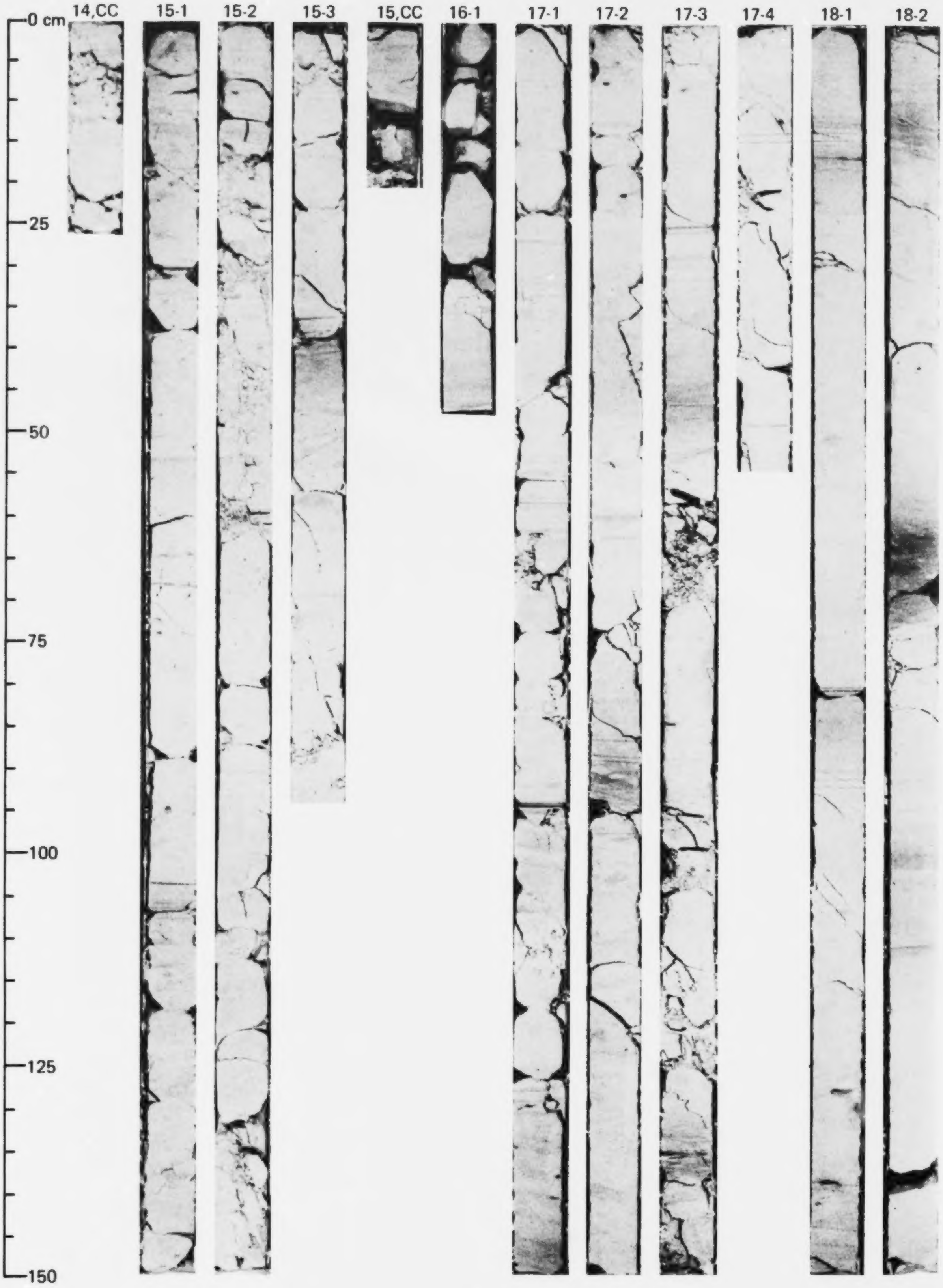
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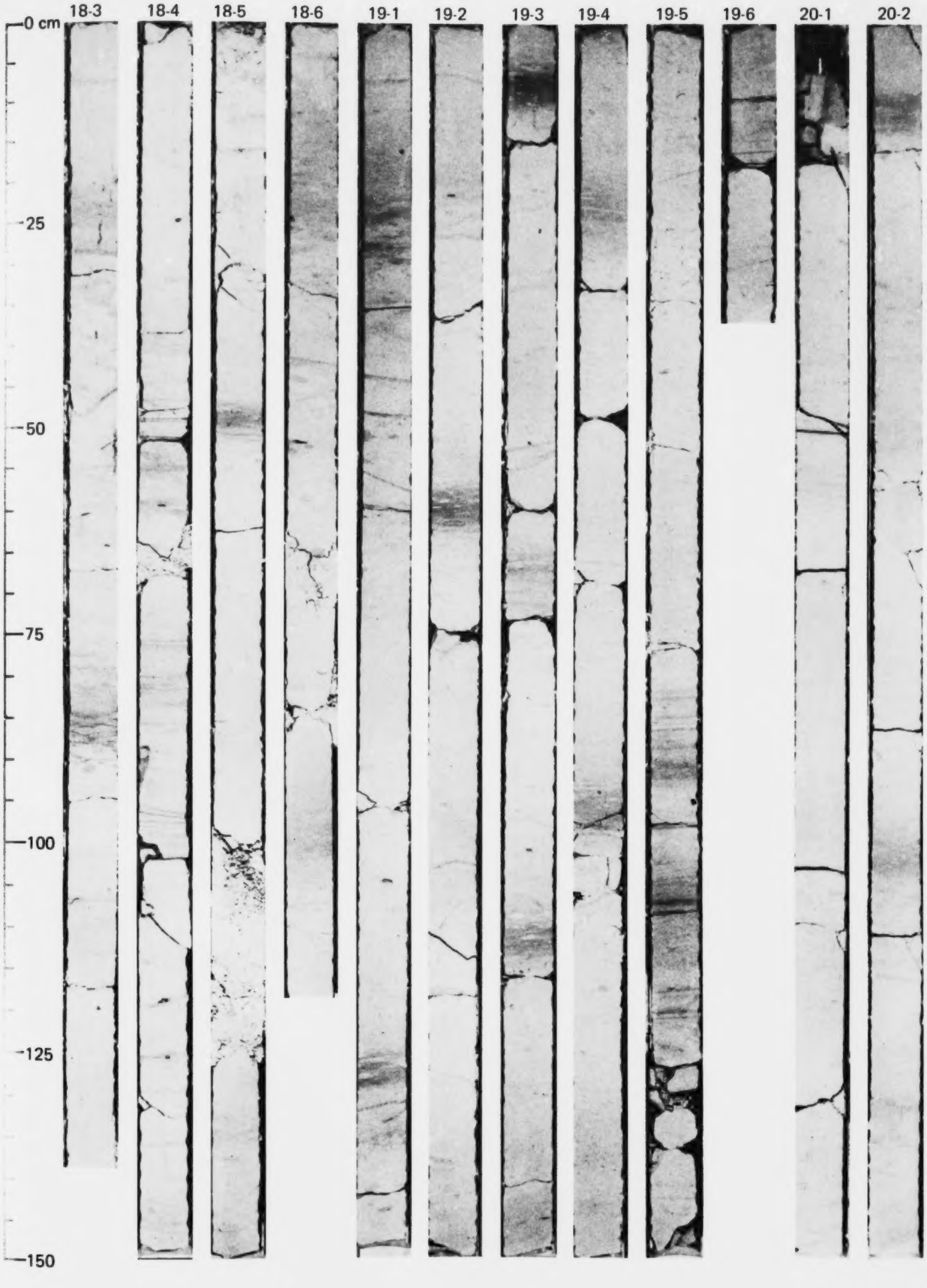
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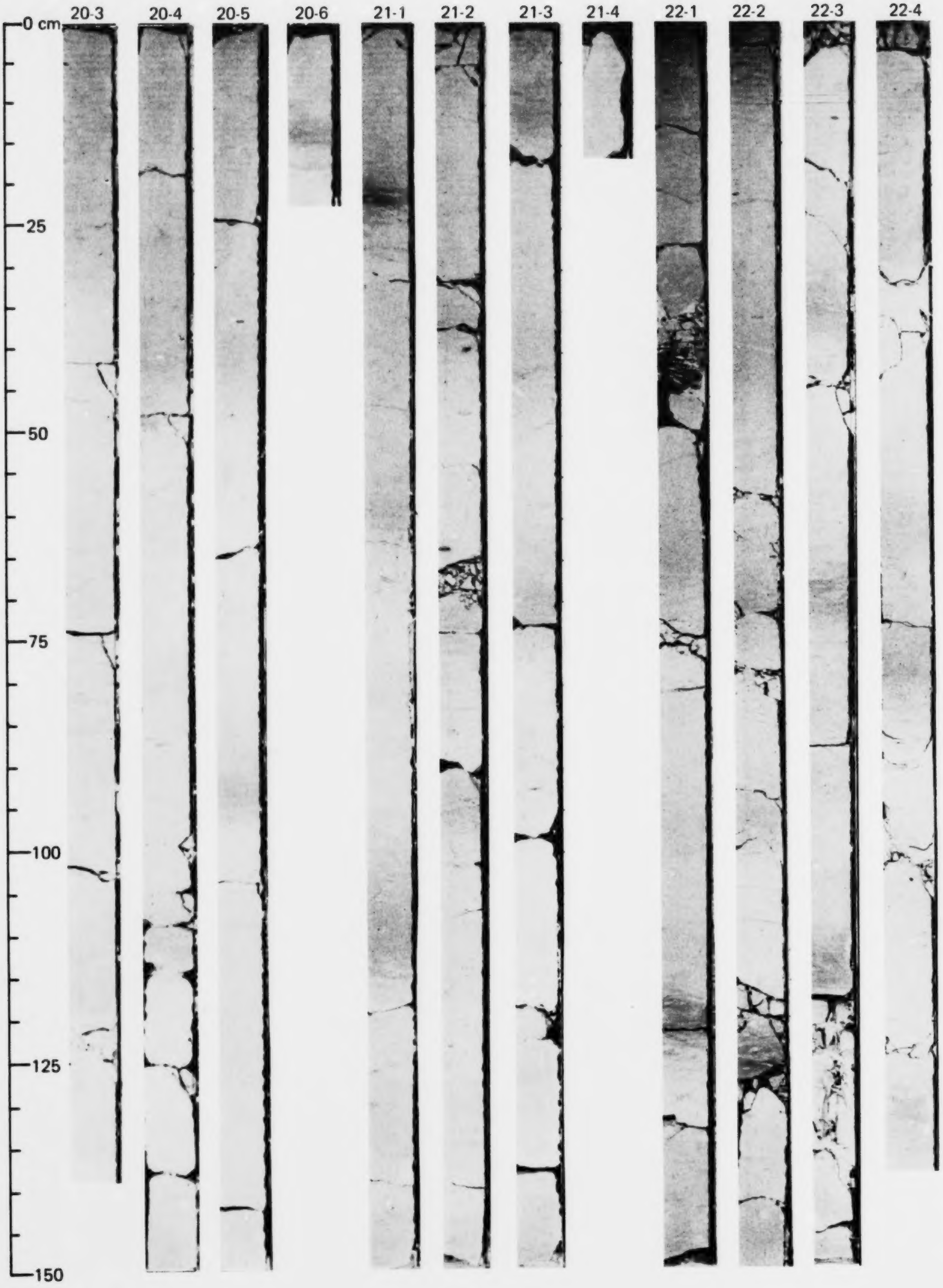
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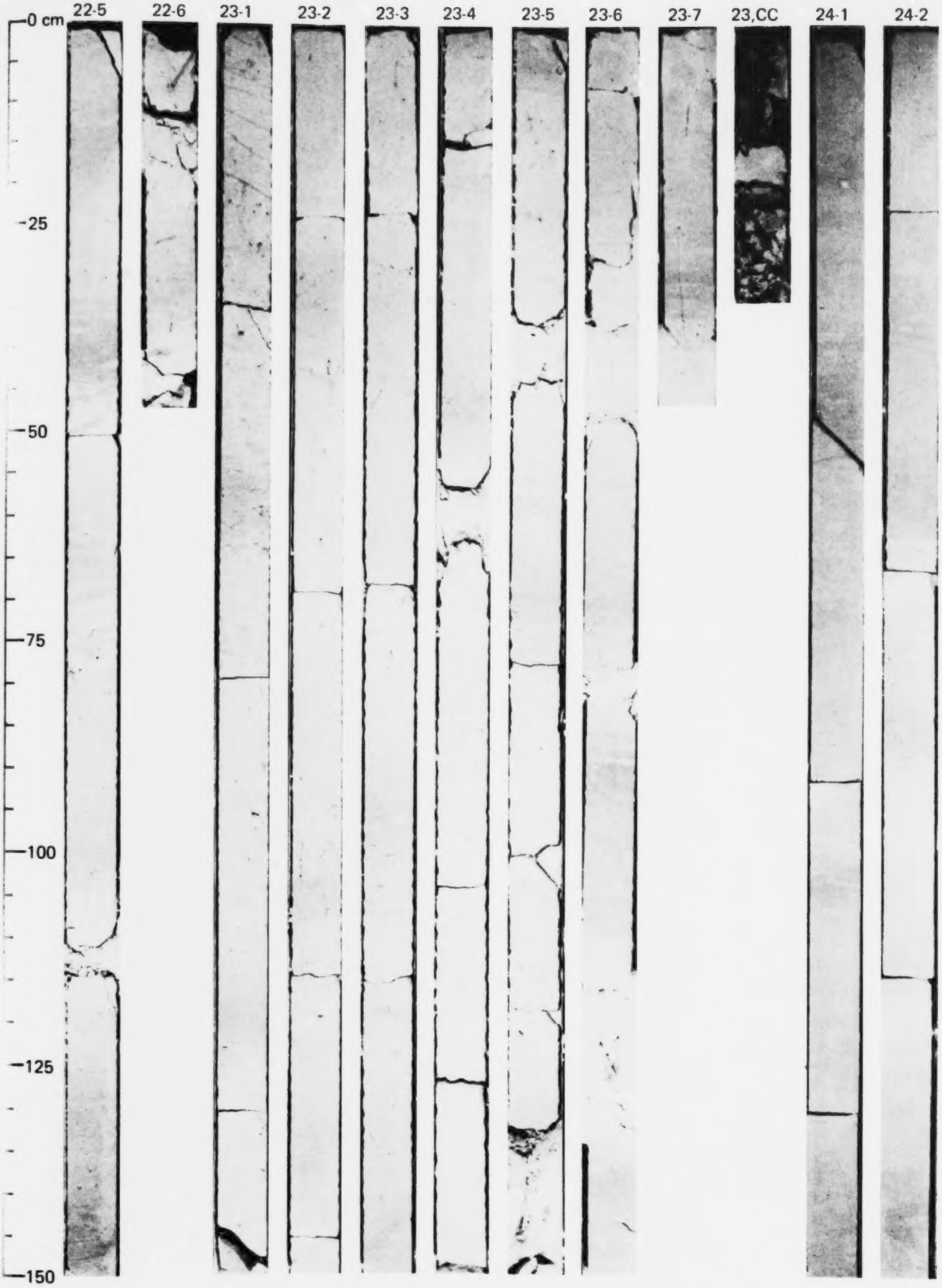
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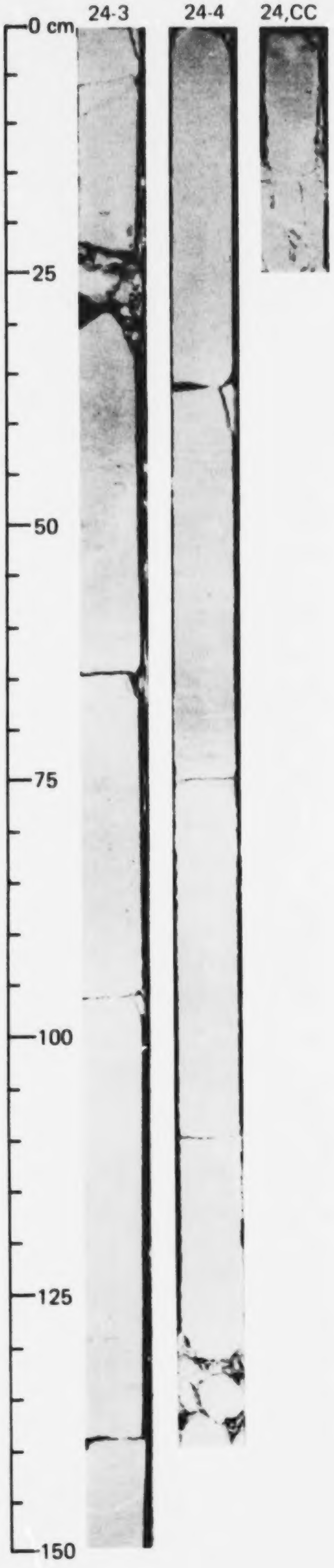
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8. SITE 592: LORD HOWE RISE, 36°S[1]

Shipboard Scientific Party[2]

HOLE 592

ate occupied: 25 December 1982

ate departed: 27 December 1982

ime on hole: 46.5 hr.

osition: 36°28.40′S; 165°26.53′E

ater depth (sea level; corrected m, echo-sounding): 1088 m

ater depth (rig floor; corrected m, echo-sounding): 1098 m

ottom felt (m, drill pipe): 1099

enetration (m): 388.5

umber of cores: 41

otal length of cored section (m): 388.5

otal core recovered (m): 340.12

ore recovery (%): 87.5

Oldest sediment cored:
Depth sub-bottom (m): 388.5
Nature: Nannofossil chalk
Age: Middle late Eocene (Kaiatan Stage of New Zealand)
Measured velocity (km/s): 1.807 km/s at 383 m
Shear strength: 350 g/cm^2 at 353 m;
greater values below

Basement: Not reached

Principal results: Site 592, drilled on the southern Lord Howe Rise (36°28.40′S; 164°26.92′E) in relatively shallow water (1088 m from sea level), consists of one hole cored continuously with the hydraulic piston cored (HPC) from 0 to 234.9 m sub-bottom and then with the extended core barrel (XCB) from 234.9 to 388.5 m. The section recovered consists of a single lithostratigraphic unit that varies from foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk). The age of the section is from middle late Eocene (42 m.y.) to Quaternary. The bottom of the hole consists of 83.5 m of Paleogene ooze and chalk ranging in age from the late Eocene to the early Oligocene (35 m.y. ago). The regional unconformity of the southwest Pacific separates the lower Oligocene sediments from immediately overlying middle lower Miocene sediments 18.5 m.y. old. The section is represented by a section of high-quality cores with almost complete recovery from the middle Miocene to Quaternary using the HPC, and a less complete but still excellent section recovered at greater depths using the extended core barrel. A paleomagnetic polarity stratigraphy has been identified down to the late Gauss Chron (2.5 m.y. ago).

The section has been divided into five subunits: Subunit IA represents a veneer (0.0–0.3 m) of pale orange to pinkish gray foraminifer-bearing nannofossil ooze within the oxidized zone near the seafloor. Subunits IB to IE are differentiated by degree of lithification. There is good foraminifer preservation in the Neogene and Oligocene, whereas the nannofossils are only well preserved in the late Neogene and Oligocene. Radiolarians are present in small amounts only in the Eocene. The biostratigraphic sequences seem to be complete except for that part missing in the regional unconformity. Sedimentation rates range from lowest values (7 m/m.y.) in the late Eocene to highest value (92.5 m/m.y.) in the late early Pliocene. In general, sedimentation rates are much lower at Site 592 than in sites both to the north and south.

Of particular interest at this site is a fine complete boundary section between the Eocene and the Oligocene in Cores 592-36 and 592-37. The hiatus present in all other South Pacific sites except Site 277 in the subantarctic area south of New Zealand is not found at Site 592. A distinct lithologic change occurs near the level of extinction of *Globigerinatheka index*, which is the foraminifer marker for the boundary in south temperate latitudes. The late Eocene is represented by nannofossil chalks containing siliceous microfossils such as radiolarians and sponge spicules, the Oligocene by surprisingly soft nannofossil ooze lacking biosiliceous materials. The section provides good opportunities for high-resolution stratigraphy across the boundary.

Volcanic ash layers or altered laminae occur in the Quaternary, early late Miocene (10 m.y.), and through the Paleogene.

Good benthic foraminifer and ostracode assemblages occur throughout much of the sequence and exhibit changes at a number of levels associated with paleoceanographic events.

BACKGROUND AND OBJECTIVES

Site 592 (SW-2) is located near the southern end of Lord Howe Rise, about 60 km north of Site 207 (Fig. 1), and was selected from the *Glomar Challenger* Leg 21 profile recorded at 1900 hr., 15 December 1971.

Site 207 was located in an area of thin (360 m) sediment cover overlying a basement high composed of rhyolite. At Site 207, the upper 142 m of sediment cover consists of a thin middle Miocene to Quaternary sequence of foraminifer–nannofossil ooze, which is unconformably underlain by siliceous calcareous and calcareous oozes of Eocene age. The Neogene sediments clearly were winnowed at Site 207, judging by the low sedimentation rates and relatively high proportion of foraminifers. The basement high upon which Site 207 is located had focused bottom currents during the Cenozoic.

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. ovt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), hool of Earth Sciences, Flinders University of South Australia, Bedford Park, South Aus- alia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; arles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narra- nsett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, ny Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National d'His- e Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Sciences sion, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 96720; es V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 345 dlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Sciences, n University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United King- William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, Little- CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgang- the Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic ermany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Ocean- phy, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, ege Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Sci- , Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. logical Survey, Denver Federal Center, Denver, CO 80225); Campbell S. Nelson, Depart- t of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Chris- Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 88 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu ersity, Varanasi 221 005, India; Rudiger Stein, Geologisch-Paläontologisches Institut, ersität Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petro- m and Organic Geochemistry (ICH-5), Kernforschungslage Jülich GmbH, P.O. Box 1913, 0 Julich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, ulty of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

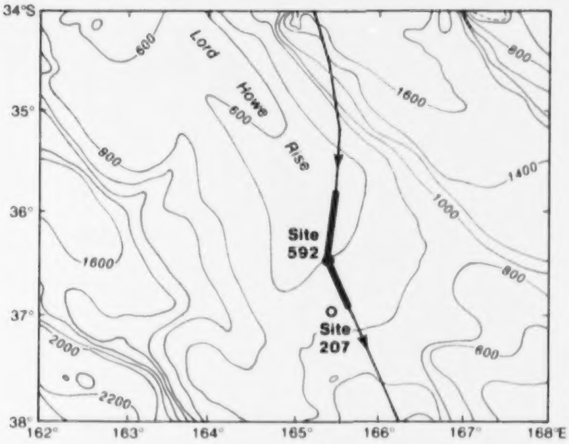


Figure 1. Regional bathymetry (fathoms) around Site 592, after Mammerickx et al., 1974. *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

Since the primary objectives of Leg 90 were related to paleoceanographic history, rather than to basement problems, a site was chosen in an area of thick (600 m) sediment cover close to Site 207. The seismic profile (Fig. 2) shows that this location is represented by relatively transparent sediments that probably are not complicated by bottom current activity.

Site 592 was proposed by the JOIDES Paleoenvironmental Panel as a secondary objective because it lies in the same cool-temperate water mass as Leg 29, Site 284. Precruise calculations indicated that there would be time for only one site located in the cool-temperate water mass. Since Site 284 was in thicker Neogene sediments, it was designated the primary site (SW-2). However, the discovery during Leg 90 of spectacularly high rates of calcareous biogenic sedimentation during the Pliocene in the area of Sites 590 and 591 (about 31°S) led to much interest in determining if these are of local nature or if they extend further south to the area of Site 592. We had already determined that such high sedimentation rates do not seem to occur in the northern Lord Howe Rise area (Site 588).

A total of only two days could be budgeted toward the drilling of Site 592. Nevertheless, we believed that if we managed to determine sedimentation rates for the Pliocene Epoch only it would be a successful use of the two days assigned for this experiment. A total of two days on the site would allow time for only one HPC hole and perhaps a short sequence using the extended core barrel.

The objectives for drilling Site 592 were much the same as for the other sites drilled near the crest of Lord Howe Rise. In particular, a sequence was needed for the following studies:

1. To compare and contrast rates of calcareous biogenic sedimentation between other Lord Howe Rise sites and Site 592, in an area with much less evidence of winnowing than at Site 207.
2. To provide another late Neogene sequence intermediate in latitude between Sites 590 and 593. This should help in cross-latitudinal correlation.
3. To provide another Neogene sequence of shallower-water benthic foraminifers for studies of possible north-south biogeographic differences in assemblages at similar water depths. There are few data available to show whether faunas within the same intermediate water masses exhibit changes with changing latitude. The general assumption is that little biogeographic change does occur within the same deeper-water masses in the oceans.
4. To provide a longer Neogene and perhaps Paleogene sedimentary record than was available at Site 207.

OPERATIONS

Site 591 to Site 592

A combination of good average speed between sites, very few mechanical breakdowns, little time lost waiting on weather, and no drilling problems all combined at this point in the voyage to indicate that operations were well ahead of schedule. Continued use of the XCB and continuation of the excellent vessel speed was expected to further improve the schedule. Given all this, enough

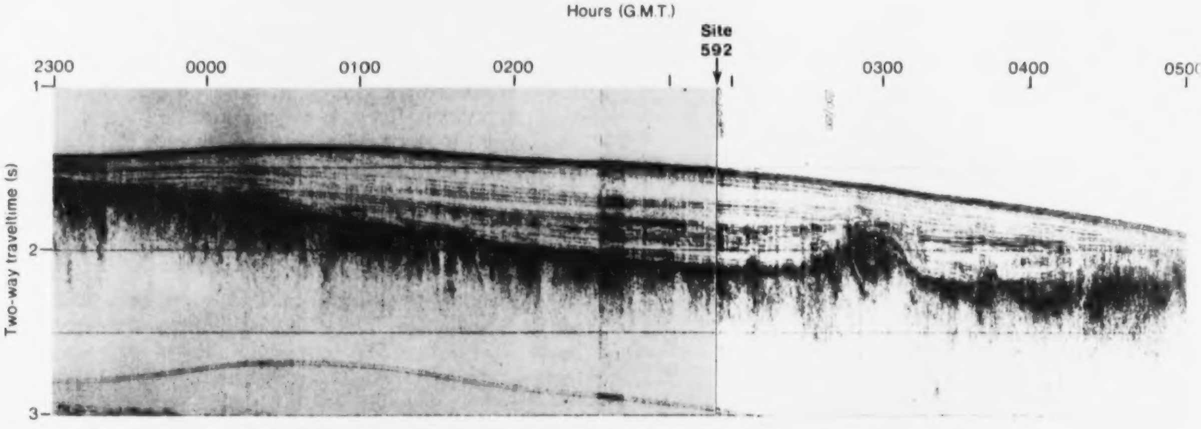


Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 592; bandpass filter 40–160 Hz.

extra time was anticipated to allow coring contingency Site SW-3.

The vessel made its way south to the chosen site coordinates without incident. The beacon (16.0 kHz, D.L.) was dropped on the first pass at 1416 hr., 25 December 1982.

Site 592 (SW-3): Southern Lord Howe Rise

The operating plan for the site was to obtain a good piston-cored sequence through the Neogene sediments to refusal and then to deploy the XCB, in order to test it under modified operational practices and, if possible, to core into stiffer sediments as far as the Oligocene/Eocene boundary. The time on site was to be limited to 48 hr.

Although weather conditions were not good, the vessel was able to be positioned with her bow into the prevailing wind and swell so that positioning in automatic with tolerable roll and pitch was relatively easy.

A combination XCB/variable length (VL) HPC bottom-hole assembly was made up as before and run to the height chosen for the mud line core attempt. Hole 592 was spudded at 2035 hr. with a VLHPC mud line core (Table 1), which established the water depth to be 1099.7 m by drill pipe measurement.

A rig floor failure of a small threaded connection caused the loss of the lower portion of the Kuster orientation tool pressure case just prior to running in for the second piston core. This was the only weather-related mishap at the site. Fortunately the plan had been to deploy the Kuster tool starting with the third core so the tool itself was not installed at that time.

Table 1. Coring summary, Site 592.

Core No	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
1	25	2105	1099.7-1104.2	0.0-4.5	4.5	4.45	98.8
2	25	2230	1104.2-1113.8	4.5-14.1	9.6	9.52	99.1
3	25	2330	1113.8-1123.4	14.1-23.7	9.6	9.41	98.0
4	26	0025	1123.4-1133.0	23.7-33.3	9.6	9.43	98.2
5	26	0100	1133.0-1142.6	33.3-42.9	9.6	9.54	99.3
6	26	0145	1142.6-1152.2	42.9-52.5	9.6	9.31	97.0
7	26	0225	1152.2-1161.8	52.5-62.1	9.6	9.32	97.0
8	26	0310	1161.8-1171.4	62.1-71.7	9.6	9.01	93.8
9	26	0355	1171.4-1181.0	71.7-81.3	9.6	9.30	96.9
10	26	0450	1181.0-1190.6	81.3-90.9	9.6	9.50	98.9
11	26	0535	1190.6-1200.2	90.9-100.5	9.6	8.02	83.3
12	26	0610	1200.2-1209.8	100.5-110.1	9.6	9.71	100+
13	26	0700	1209.8-1219.4	110.1-119.7	9.6	8.59	89.4
14	26	0745	1219.4-1229.0	119.7-129.3	9.6	9.70	100+
15	26	0815	1229.0-1238.6	129.3-138.9	9.6	9.18	95.6
16	26	0900	1238.6-1248.2	138.9-148.5	9.6	9.69	100+
[illegible]	26	0930	1248.2-1257.8	148.5-158.1	9.6	8.48	88.3
[illegible]	26	1015	1257.8-1267.4	158.1-167.7	9.6	9.66	100+
	26	1100	1267.4-1277.0	167.7-177.3	9.6	8.76	91.2
	26	1150	1277.0-1286.6	177.3-186.9	9.6	9.68	100+
	26	1235	1286.6-1296.2	186.9-196.5	9.6	9.60	100+
	26	1330	1296.2-1305.8	196.5-206.1	9.6	9.42	98.1
	26	1420	1305.8-1315.4	206.1-215.7	9.6	9.69	100+
	26	1520	1315.4-1328.0	215.7-225.3	9.6	9.08	94.5
	26	1615	1328.0-1334.6	225.3-234.9	9.6	9.77	100+
	26	1735	1334.6-1344.2	234.9-244.5	9.6	9.50	99.9
	26	1845	1344.2-1353.8	244.5-254.1	9.6	0.0	0
	26	2145	1353.8-1363.4	254.1-263.7	9.6	9.58	99.8
	26	2240	1363.4-1373.0	263.7-273.3	9.6	8.67	90.3
	26	2340	1373.0-1382.6	273.3-282.9	9.6	8.44	87.9
	27	0010	1382.6-1392.2	282.9-292.5	9.6	7.94	82.7
	27	0100	1392.2-1401.8	292.5-302.1	9.6	8.03	83.6
	27	0140	1401.8-1411.4	302.1-311.7	9.6	7.05	74.4
	27	0205	1411.4-1421.0	311.7-321.3	9.6	6.31	65.7
	27	0300	1421.0-1430.6	321.3-330.9	9.6	8.13	84.6
	27	0510	1430.6-1440.2	330.9-340.5	9.6	4.78	79.6
	27	0600	1440.2-1449.8	340.5-350.1	9.6	5.44	56.6
	27	0645	1449.8-1459.4	350.1-359.7	9.6	9.05	94.2
	27	0730	1459.4-1469.0	359.7-369.3	9.6	5.52	57.5
[illegible]	27	0830	1469.0-1478.6	369.3-378.9	9.6	6.83	71.1
[illegible]	27	0910	1478.6-1488.2	378.9-388.5	9.6	9.03	94.0
					388.5	340.12	87.5

Piston coring with the 9.5-m VLHPC using two shear pins continued smoothly despite blustery weather. Full stroke was achieved on all cores. Core quality was not up to normal VLHPC standards, mainly because of the vessel's significant heave. At the 25th VLHPC core, an overpull of 25,000 lb. was required while inching the tool free. Piston coring was then terminated and the sinker bars were changed in preparation for XCB coring. The first XCB was deployed without problems and recovered a good core. The second XCB was initially stuck at the top of the BHA, and then jarred loose.

It was clear that the XCB latch was still causing problems, so the remainder of the hole was cored by running the XCB in on the wire line. One other XCB barrel, Core 592-36, did become stuck. It was dislodged by hammering with the deplugger barrel on the wire line. Core 592-36 suffered some disturbance as a by-product of the unjamming procedure.

The hole was cored to its full scientific objective plus two or three extra cores and was terminated to allow the pipe to be pulled and the ship to get under way within the original 48-hr. time limit.

LITHOSTRATIGRAPHY

Site 592 consists of one hole cored continuously with the HPC from 0–234.9 m sub-bottom and then with the XCB from 234.9–388.5 m sub-bottom. Although the hole was cored continuously, recovery is not complete and decreases below 240 m sub-bottom in the rotary-cored sequence. Cores 592-29 to 592-33 are moderately disturbed by drilling and are broken into separated biscuits. The sequence recovered consists of one lithostratigraphic unit that varies from foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk). The unit is divided into five subunits (Table 2). Subunit IA (0–0.3 m) is distinguished from Subunit IB by its very pale orange to pinkish gray color. This uppermost part of the site, which corresponds to Subunit IA in most other sites drilled during Leg 90, is the oxidized zone of the sediment section. The upper part of Subunit IB, between 0.3 and 33.3 m, is marked by alternating layers ranging in color from pale olive to white and very light gray

Table 2. Lithostratigraphy at Site 592.

Lithological subunits	Cores	Sub-bottom depth (m)	Description	Age
IA	1	0–0.3	Very pale orange to pinkish gray foraminifer-bearing nannofossil ooze	late Quaternary
IB	1-29	0.3-273.3	White to light gray foraminifer-bearing nannofossil ooze to nannofossil ooze	late Quaternary to early Miocene
IC	30-33	273.3-305.8	White to very light greenish gray foraminifer-bearing nannofossil chalk to nannofossil chalk	early Miocene
ID	33-37	305.8-350.1	White to very light gray nannofossil ooze	early Oligocene to late Eocene
IE	38-41	350.1-388.5	White to very light gray nannofossil chalk	late Eocene

(Cores 592-1 to 592-4; Pleistocene to upper Pliocene). White to very light gray dominate from 33.3 to 302.1 m. Subunit IC (273.3–305.8 m) is a chalk. The sediment from 305.8–350.1 m sub-bottom (Subunit ID), just below the early Miocene/early Oligocene unconformity, is an ooze. The white to very light colored sediment sequence contains numerous pale green laminae (Fig. 3). The lower part of Subunit ID is marked by a chert nodule surrounded by a 15-cm-thick layer of lithified limestone. The transition zone between Subunits ID and IE, from an ooze to a firm recrystallized chalk, occurs between 350 and 369 m. Light gray to medium gray blebs, pockets, and laminae are rare to occasional in Cores 592-1 to 592-16 and 592-22 to 592-37, and moderate in 592-17 to 592-21 and 592-38 to 592-41.

Calcareous nannofossils are the dominant component (about 75%) of the entire sediment sequence. Foraminifers vary from less than 5 to 25% (Fig. 4). Beds containing numerous 1–4-cm-sized molluscan (*Ostrea*) fragment occur in Section 592-34-3. Chert nodules are present i Cores 592-36-3 and 592-41-5. Noncarbonate component occur only in trace abundances (Fig. 4): volcanic glas and pyrite occur throughout the entire sequence, wher as quartz, feldspar, and heavy minerals are found onl occasionally. Biogenic opal is absent except at the top Core 592-1 and in the Eocene section (Cores 592-37 592-41), where radiolarians and sponge spicules occur trace amounts (Fig. 4).

Some pale olive intervals in the upper part and som grayish green to pale green pockets in the lower part the sediment sequence are characterized by more common volcanic glass (Fig. 4). The pale olive intervals the Quaternary–upper Pliocene sediments and the pa green laminae in the lower Oligocene–upper Eocene se

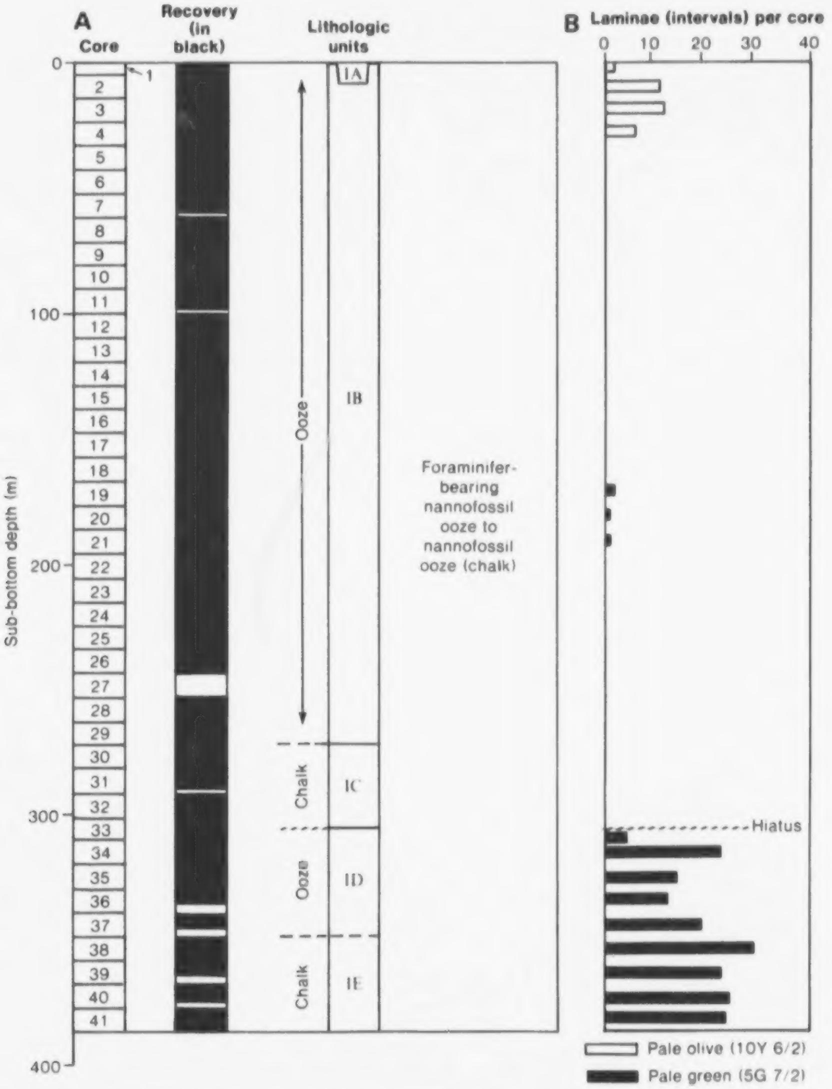


Figure 3. A. Summary of core recovery and lithostratigraphic units at Site 592. B. Laminae of volcanic ash(?) observed in core at Site 592.

iments (Fig. 3) may represent periods of increased volcanic ash supply.

Bioturbation is rare in the upper part of the sequence (Cores 592-1 to 592-30). Burrows are occasionally observed as pale olive to yellowish gray mottles and blebs. Cores 592-31 to 592-41 are moderately bioturbated with Zoophycos, Planolites and Chrondrites all evident.

PHYSICAL PROPERTIES

Site 592 provided 388 m of sediment recovery. The standard suite of gravimetric, acoustic velocity, and shear strength measurements was performed at prescribed intervals and the continuous scanning GRAPE apparatus was employed on selected cores (see Introduction for details of specific methods). A full discussion of the physical properties results for Site 592 is presented by Morin (this volume).

The GRAPE porosity results (points) are plotted versus depth in Figure 5A. These data were derived directly from the GRAPE wet-bulk densities by assuming a grain density of 2.691 g/cm^3. A mean porosity is determined across each meter of depth and these averages are plotted as the solid line. Porosity does not show the usual signs of gradual decline with increasing lithostatic load, but remains relatively constant over several hundred meters (90–290 m).

The results of the compressional wave velocity and shear strength measurements performed on split cores, parallel to bedding, are shown in Figure 5B and C, respectively. Both graphs show a coincident increase in each property at a depth of approximately 260 m, followed by an equally sharp decline at 290 m. This spike corresponds to the onset of chalk at the former depth, followed by a reintroduction of calcareous ooze. The ooze layer quickly undergoes a transition to chalk again at a depth of approximately 320 m. This behavior is reflected in increases in the matrix modulus properties at the appropriate depth. Below 355 m, the sediment shear strength is beyond the range of the miniature vane shear apparatus.

The GRAPE porosity data are combined with the compressional velocity results in order to develop a relationship between porosity and velocity (Fig. 5D). A similar analysis yields a relationship between porosity and shear strength (Fig. 5E). The shear strength is seen to rise sharply as a declining porosity approaches 52%. The velocity data are also correlated with the GRAPE wet-bulk density profile, and a record of acoustic impedance versus depth is established (Fig. 5F). Fluctuating values of impedance at a depth of about 300 m correspond to the ooze-to-chalk transitions observed at this level.

SEISMIC STRATIGRAPHY

Figure 6A illustrates a portion of the shipboard water gun seismic profile collected during the approach to Site 592. Figure 6B is a line-drawing of the profile. Three acoustic units have been identified (A, B, and C) and these are compared in part with the lithology of the site (lithostratigraphic Units IA–IE).

Acoustic Unit A incorporates a relatively transparent zone with numerous laterally continuous low-amplitude reflectors. In the region of Site 592 these reflectors are parallel to the sediment/water interface, suggesting that the area is not undergoing erosion. About 90 km to the north, however, upper reflectors of Unit A have been truncated by erosion over a broad basement high.

Acoustic Unit B marks a zone of parallel reflectors with somewhat higher amplitude. These reflectors are parallel to those of Unit A.

Acoustic Unit C incorporates a well-defined series of relatively high amplitude parallel reflectors. Subtle truncation of reflectors immediately below the top of Unit C by base of Unit B, visible immediately north of Site 592 (Fig. 6B), suggests minor erosional truncation of strata at the upper limit of Unit C. In addition, all reflectors of Unit C can be seen to onlap the strong basement reflector when traced to the north.

Acoustic basement in the region is very smooth.

Lithostratigraphic Units IA, IB, IC and ID comprise a visually monotonous sequence of foraminifer-bearing nannofossil ooze to nannofossil ooze, ranging in age from Quaternary to the late Eocene. Within this section, gradational boundaries between ooze and chalk occur at about 272 and 345 m sub-bottom. The upper chalk horizon actually reverts to ooze at 306 m sub-bottom before becoming chalky again between 345 m and the bottom of the hole. A distinct hiatus was shown to exist at 306 m sub-bottom, separating the late early Miocene from the early Oligocene. Below this a continuous sequence was cored across the Oligocene/Eocene boundary.

In matching the lithology with the seismic profile at Site 592 we tentatively assume an interval velocity of 1700 m/s, averaged from shipboard velocimeter measurements. Comparisons suggest that the boundary between acoustic Units A and B does not coincide with the onset of chalkiness, as hypothesized at earlier sites. Rather, it appears due to a subtle and undetermined change in acoustic impedance which is not obvious from the lithology or physical properties. The strong reflector marking the upper limit of Unit C may be correlated with the top of lithostratigraphic Unit IC, at which level chalk is first observed. This level also coincides with the low-angle truncation surface already described.

Lithostratigraphic Unit ID, an ooze which is sandwiched between two chalk horizons (IC and IE), appears to correlate with a slightly more transparent zone within acoustic Unit C, and the top of lithostratigraphic Unit IE appears to match a strong reflector within acoustic Unit C.

BIOSTRATIGRAPHY

Site 592 was drilled on the southern end of the Lord Howe Rise, at latitude 36°28.40′S, longitude 165°26.35′E in a water depth of 1088 m below sea level; this is just north of DSDP Site 207, drilled on Leg 21. The nannofossil preservation and planktonic foraminiferal zones of Site 592 are shown in Figure 7.

The preservation and abundance of planktonic foraminifers were good for the Neogene and Oligocene but deteriorated in the Eocene; the benthic foraminifers are well preserved down to the upper Miocene, then deteriorate in the lower Miocene, improve in the Oligocene, and again deteriorated in the upper Eocene. Nannoplankton preservation is good for the Quaternary and Plio-

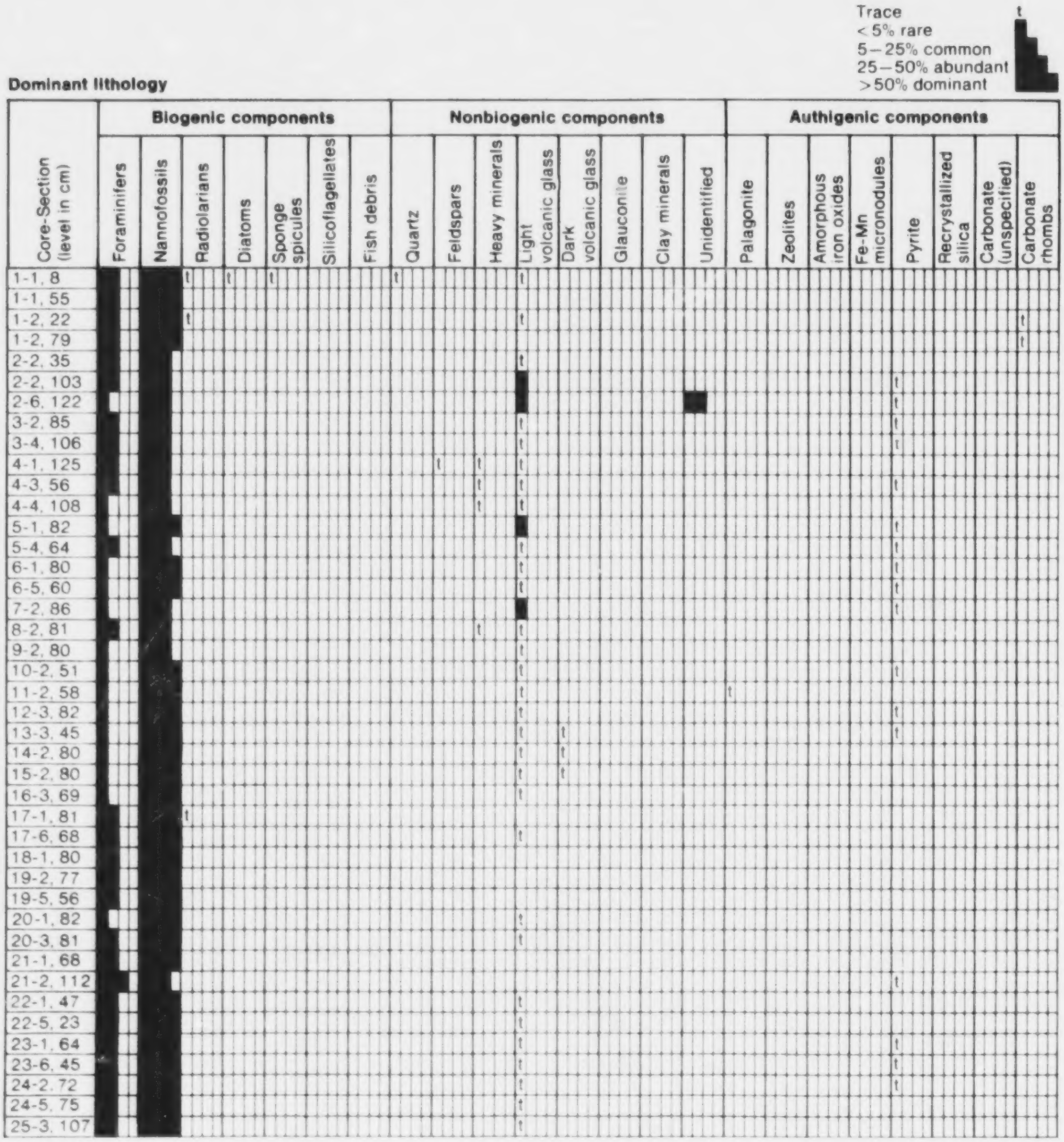


Figure 4. Smear slide summary, Site 592.

cene but deteriorates in the Miocene, and is better below the unconformity in the Oligocene, but again deteriorates in the Eocene.

Radiolarians were found to be present only in the Paleogene deposits, whereas diatoms and silicoflagellates were missing throughout. Shell fragments were noted in Core 592-34, and a more complete specimen from Section 4 was identified as *Ostrea* sp.

In terms of planktonic foraminiferal zones, the unconformity at Site 592 occurs between the lower part of the *Globigerinoides trilobus* Zone and the upper part of the *Globigerina angiporoides* Zone (i.e., between 18–19 and 31–32± m.y. ago). In terms of nannoplankton zon , the unconformity occurs between the NN2 and NP 2 Zones (i.e., between 19.5 and 35 m.y. ago).

The major boundary of interest at Site 592 is the E cene/Oligocene boundary and, following the practic n New Zealand, this was placed at the extinction of *Glo gerinatheka index*, which was noted in Section 592-3 3 between 90 and 64 cm. According to the nannoplan ton, the boundary at the extinction of *Discoaster sai nensis* is in Core 592-37-2, between 5–6 and 33–34 c . A similar sequence of extinctions for the two taxa w s recorded at DSDP Site 277, drilled south of New Zealan .

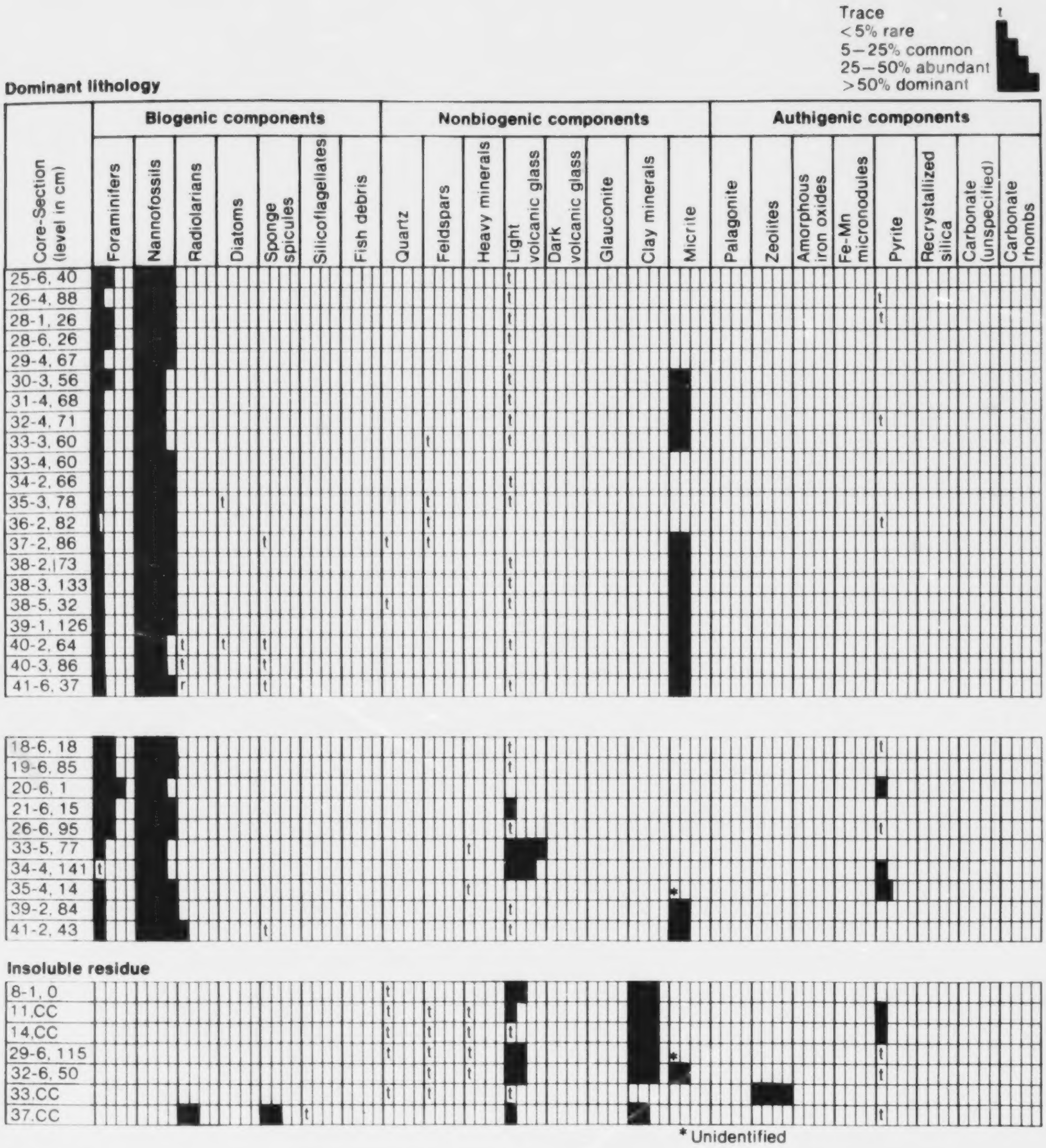


Figure 4. (Continued).

lanktonic Foraminifers

Zones

The following zones were identified at Site 592; the nal boundary markers are shown below:

Globorotalia truncatulinoides Zone
  L. A. *G. tosaensis*
Globorotalia truncatulinoides–G. tosaensis Zone
  I. A. *G. truncatulinoides*
Globorotalia inflata Zone
  I. A. *G. inflata*
Globorotalia crassaformis Zone
  I. A. *G. crassaformis*
Globorotalia puncticulata Zone
  I. A. *G. puncticulata*
Globorotalia sphericomiozea Zone
  L. A. *G. conomiozea*
Globorotalia conomiozea Zone
  I. A. *G. conomiozea*
Globorotalia miotumida Zone
  L. A. *N. continuosa*
Neogloboquadrina continuosa Zone
  L. A. *G. mayeri*

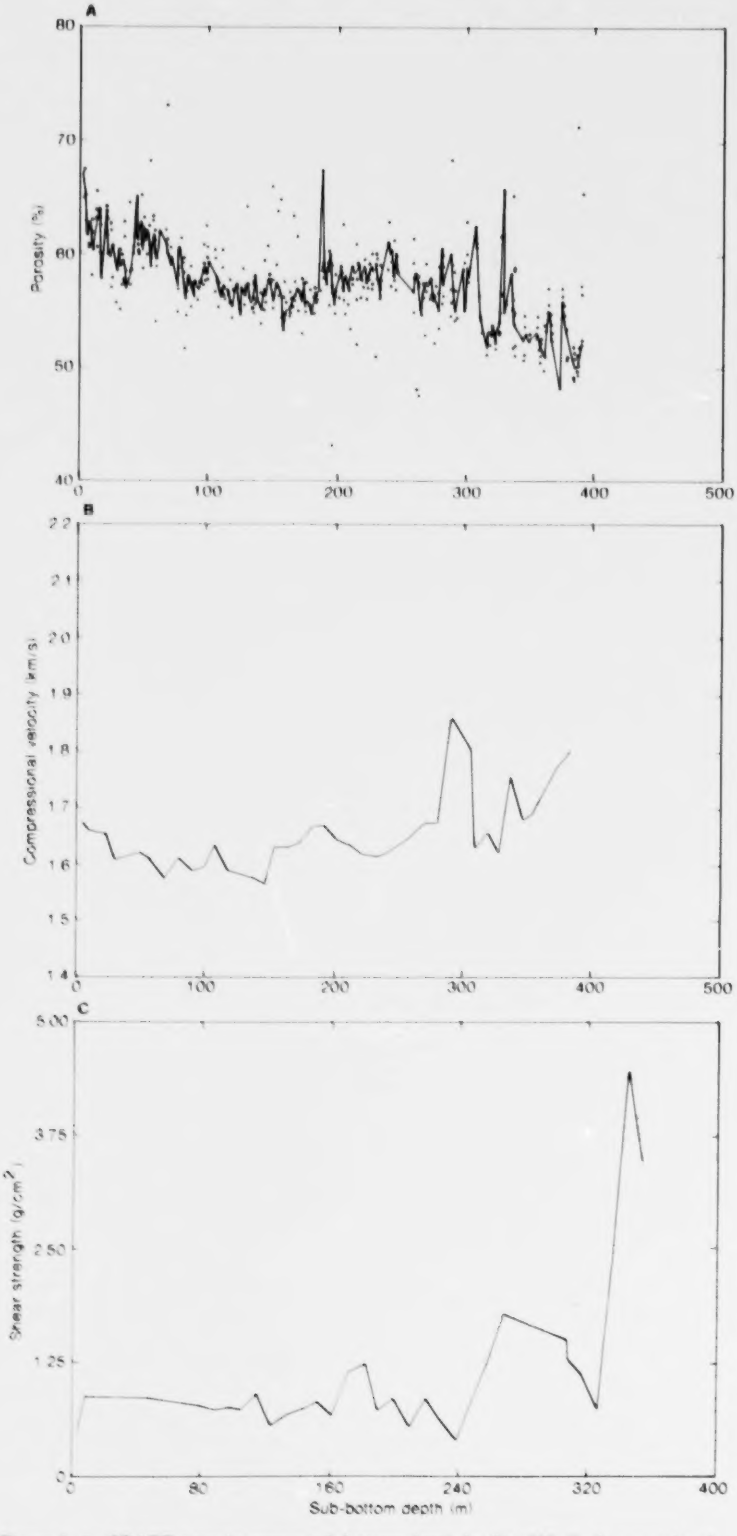


Figure 5. A. GRAPE porosity versus sub-bottom depth for Site 592. B. Compressional velocity versus sub-bottom depth for Site 592. C. Shear strength versus sub-bottom depth for Site 592. D. Porosity versus compressional velocity for Site 592. E. Porosity versus shear strength for Site 592. F. Acoustic impedance versus sub-bottom depth for Site 592.

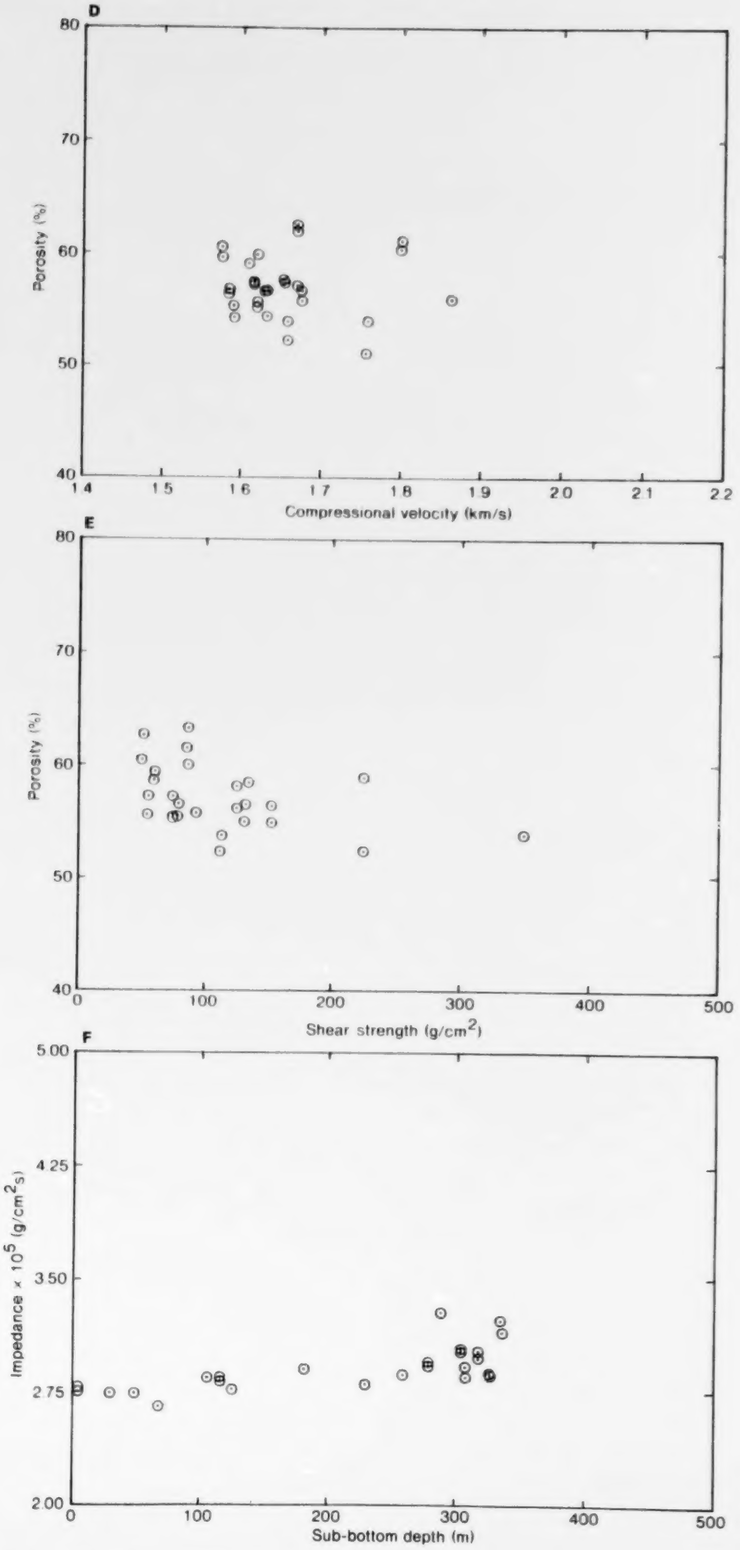


Figure 5. (Continued).

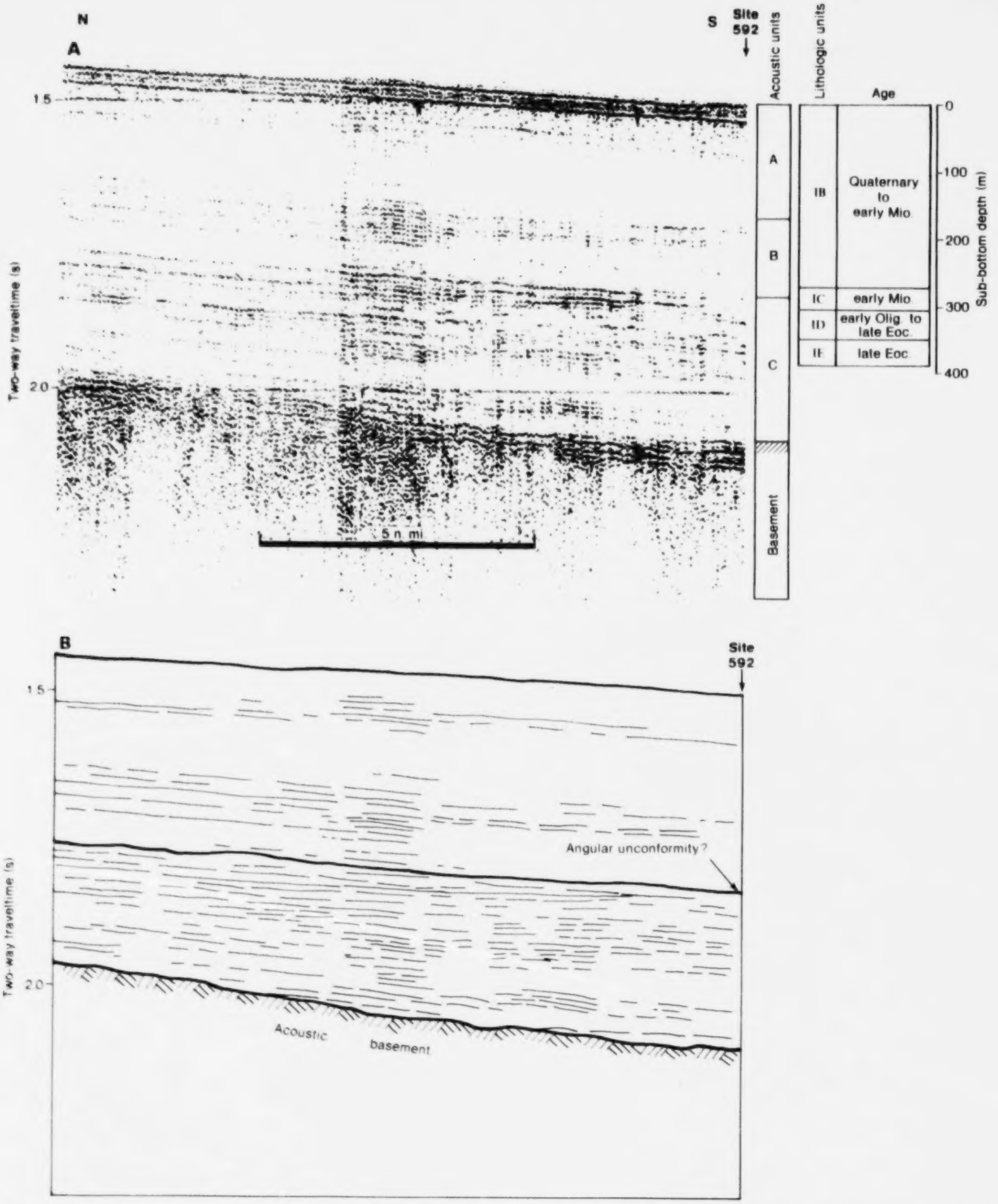


Figure 6. A. Comparison of acoustic Units A–C with lithostratigraphic Units IA (not shown), IB, IC, ID, and IE cored at Site 592; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1700 m/s. B. Line drawing of seismic profile shown in A; note subtle angular unconformity, with truncation of strata of probable early Oligocene age.

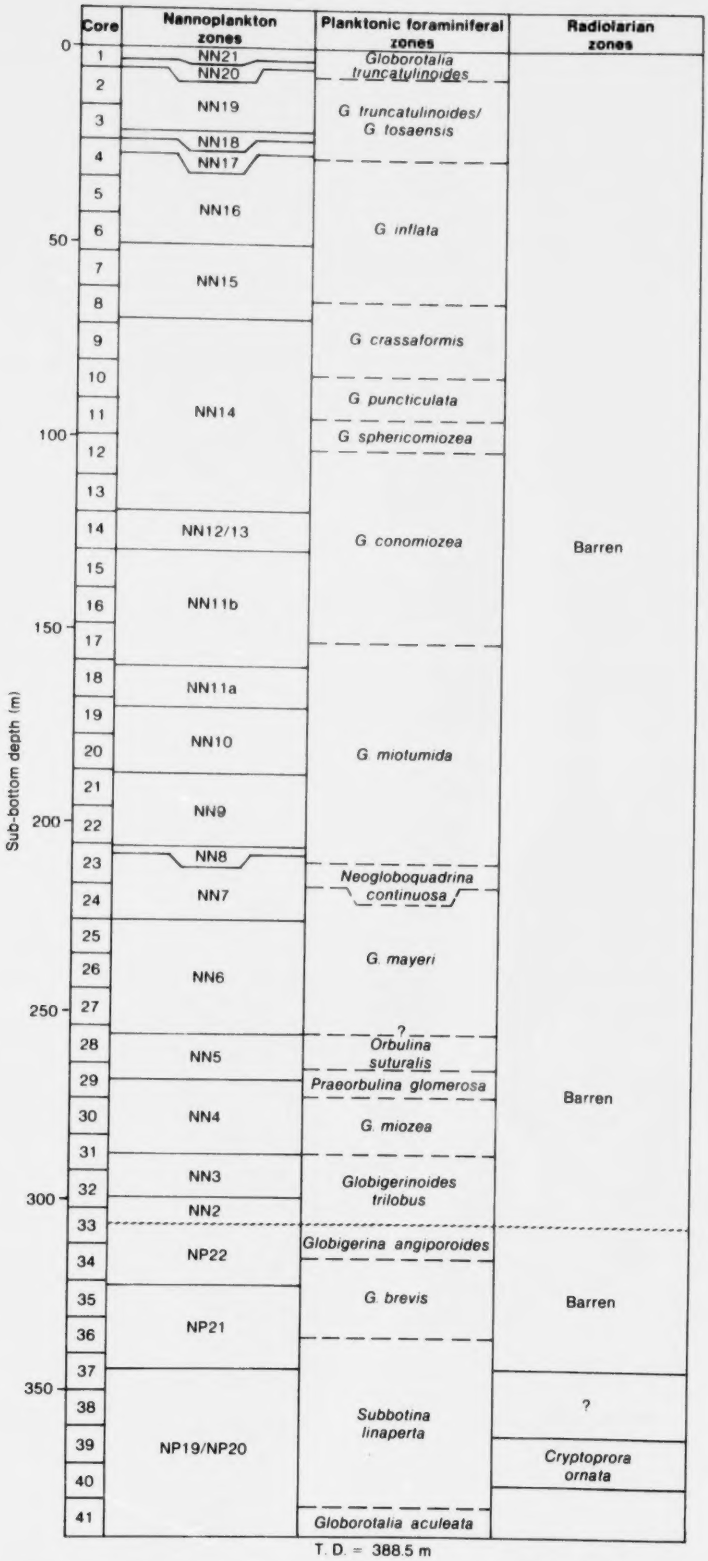


Figure 7. Comparison between calcareous nannoplankton, foraminiferal, and radiolarian zones at Site 592.

Globorotalia mayeri Zone
I. A. *G. mayeri*
Orbulina suturalis Zone
I. A. *O. suturalis*
Praeorbulina glomerosa curva Zone
I. A. *P. glomerosa*
Globorotalia miozea Zone
I. A. *G. miozea*
Globigerinoides trilobus Zone
——— UNCONFORMITY ———
Globigerina angiporoides Zone
L. A. *G. brevis*
Globigerina brevis Zone
I. A. *G. brevis*
Subbotina linaperta Zone
L. A. *G. aculeata*
Globorotalia aculeata Zone

The missing zones represented by the unconformity, in descending order, are *Globigerina connecta* Zone; *G. woodi* Zone; *G. dehiscens* Zone; *G. euapertura* Zone; *G. angiporoides* Zone (upper part only).

There were a few problems in recognizing some of the zones in the more northern sites; for example, the *Globorotalia tosaensis* Zone was not detected in the late Pliocene. The best explanation for its absence below the first appearance of *G. truncatulinoides* is that *G. tosaensis* evolved from *G. crassaformis* to the north of Site 592 and later spread southward with *G. truncatulinoides*; there is no hiatus.

The *N. continuosa* Zone is based on the range of the zonal marker after the extinction of *G. mayeri*. It is not a satisfactory zone because *N. continuosa* is rare and it is not known whether the extinction level is diachronous. The *G. fohsi* s.l. Zone was not recognized at Site 592 because *Fohsella* species are missing at this site.

Faunas

The planktonic foraminifers are abundant and well preserved from the Pleistocene to the Oligocene, but there is a marked deterioration in preservation in the late Eocene.

The Neogene faunas indicate temperate conditions with a few incursions of warmer water from the north; such warm incursions were detected in Samples 592-6,CC, 592-8,CC, 592-10,CC, 592-16,CC, and 592-17,CC. Because of the cooler-water conditions none of the following taxa were found: *Pulleniatina, Globorotalia menardii, Sphaeroidinella dehiscens, Catapsydrax dissimilis*, and *C. stainforthi*: *G. margaritae* is rare. The cooler-water species *G. conica* was present in the *G. mayeri* Zone; its northern paleogeographic limit is probably close to Site 592.

The Paleogene faunas are similar to those found in New Zealand and Victoria, Australia. The relatively low diversity in some of the late Eocene samples is due mainly to poor preservation, but the low diversity in the Oligocene is due to the cool-water conditions which prevailed at that time.

Unconformity and Major Boundaries

The unconformity between the *Globigerina angiporoides* Zone and the *Globigerinoides trilobus* Zone is a regional hiatus and was first detected in the Tasman Sea by the scientists of DSDP Leg 21 (Burns, Andrews, et al., 1973). The uppermost samples below the unconformity contained both *Globorotalia munda* and *Chiloquembelina cubensis, Globorotaloides testarugosa*, and *Globigerina ampliapertura,* which suggests that this is in the upper part of the *G. angiporoides* Zone. The extinction of *C. cubensis* slightly later in the late Oligocene has been dated by Berggren (1972) at about 30 m.

The lowermost lower Miocene above the unconformity is within the *Globigerinoides trilobus* Zone, above the local extinction of *Catapsydrax dissimilis*. An estimated age for this part of the zone is about 18–19 m.y. ago (Berggren et al., in press).

The unconformity at Site 592 is closer in stratigraphic position to that at Site 206 than to Site 207 drilled during Leg 21 (Fig. 8). This unconformity could be related to the initiation of the Circum-Antarctic Current, which occurred at about 29–30 m.y. ago (Jenkins, 1974; Kennett et al., 1972).

Other major boundaries noted include the following:

Pliocene/Pleistocene:	first occurrence of *Globorotalia truncatulinoides*;
Miocene/Pliocene:	extinction of *G. conomiozea*;
Eocene/Oligocene:	extinction of *Globigerinatheka index* (in Section 592-36-3, between 64 and 90 cm).

Benthic Foraminifers

Benthic foraminifers were examined in the fraction >63 μm from all core catchers taken at Site 592. Several additional samples were studied in Cores 37 and 36 across the Eocene/Oligocene boundary. Benthics are well preserved in the top of the section down to Core 23 (*Globorotalia miotumida* Zone), in which recrystallization becomes evident and faunal diversity drops markedly. Preservation worsens slightly through the lower Miocene, but improves in the lower Oligocene (Cores 592-33 to 592-36). Uppermost Eocene sediments resemble those of the lower Miocene, except that a large and diverse foraminiferal fauna was recovered.

Throughout the section, benthic faunas are dominated by species of the genera *Cibicidoides, Cibicides,* and *Bolivina*. Also common are *Melonis barleeanum, Sigmoilopsis schlumbergeri,* and, in the Paleogene, species of *Anomalinoides*. The number of New Zealand endemic species increases in the Paleogene, including such forms as *Vaginulinopsis hochstetteri, Cibicidoides molestus,* and *Rotaliatina sulcigera*. In the Neogene, species named in New Zealand are less frequent and are the same as those found at Site 591 farther to the north.

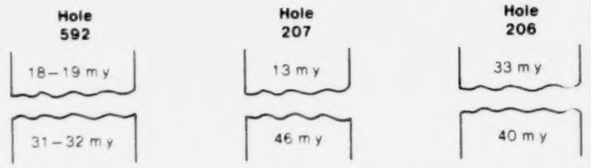


Figure 8. Comparison of unconformities in the Tasman Sea.

Downslope transport of shallower-water materials does not appear to be common at this site; exceptions are Cores 592-4, 592-22 and 592-23, which contain uncommon specimens of large, abraded, shallow-water species of *Spiroloculina* and *Ammonia*.

Typical Eocene faunas (Cores 592-41 and 592-36) contain abundant benthic individuals; common species are *C. molestus, Uvigerina bortotara* (= *U. spinicostata, U. havanensis*, and *U. rippensis*), *C. io, A. semiteres, Stilostomella nuttali*, and *Globocassidulina subglobosa*. *Vaginulinopsis* spp. are present in all Eocene samples, but disappear at the Eocene/Oligocene boundary, which is located between Cores 592-36-3, 88 cm and 592-36-2, 9 cm. Species common for the first time above the boundary include the spinose stilostomellids, *Valvulineria* sp., *Sphaeroidina bulloides, C. lobatulus* and the bolivinids. The more ornate cibicidids, with limbate sutures, become less common above the boundary.

Lower Oligocene faunas (Cores 592-36 to 592-33) resemble those of the upper Eocene, except for the larger proportions of *A. semiteres, C. io, Cibicides lobatulus*, and the striate bolivinids.

Lower to middle Miocene sediments are the least well preserved, but are better than those at the other sites drilled during Leg 90. The faunas are considered dissolution-residue faunas, but are relatively large and contain increased percentages of orbulinids from the *Globigerinoides trilobus* to the *Orbulina suturalis* Zone (Cores 592-32 to 592-28). Above this level a new fauna, still the result of dissolution, is marked by the abundant presence of *Bolivina anastomosa* (Cores 592-27 to 592-21, *Globorotalia mayeri–G. miotumida* zones).

The last change in benthic faunas of the Miocene occurs in the lower *G. conomiozea* Zone (Core 592-15), when there is an increase in the abundance of miliolids which is possibly due to better preservation and when *Anomalina semipunctata* first appears. These events occur earlier in Site 592 than in sites to the north.

A major change in sedimentation and in the diversity and abundance of benthic faunas occurs in the lower Pliocene *G. sphericomiozea–G. puncticulata* interval (Cores 592-11 and 592-10). Through the remainder of the section the abundance of benthics increases dramatically, diversity is consistently higher, but few new forms are found.

At the *G. crassaformis/G. inflata* change, which is considered to represent in the Northern Hemisphere the change to glacial conditions, the faunas change in two ways. First, *Cibicides lobatulus* increases dramatically in abundance and dominates all faunas through the remainder of the Pliocene and Quaternary. The numbers of other cibicidids and of the bolivinids also increase markedly. In addition, there is an increase in the proportion of uvigerinids, and a change in the types of uvigerinids from a *Uvigerina hispida–U. hispido-costata* assemblage below, to one dominated by the *U. peregrina* plexus, including forms tending to *U. mediterranea* and, in one sample, *U. spinulosa*. These morphotypes were not seen at the more northerly sites.

The *U. peregrina* plexus then disappears during the *G. tosaensis* interval, when miliolids again become more common in the benthic faunas; but it reappears in the Quaternary (Cores 592-2 to 592-1).

Calcareous Nannoplankton

Core-catcher samples and sufficient additional samples to determine zonal boundaries were examined for calcareous nannoplankton. All of the zonal indicators are present with the exception of *Helicosphaera ampliaperta* and *Sphenolithus pseudoradians*. The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis*, and the *Isthmolithus recurvus* Zone/*Sphenolithus pseudoradians* Zone (NP19/NP20) are combined. Calcareous nannoplankton are abundant throughout the section at Site 592. Preservation is good in the Quaternary and Pliocene. In the Miocene, preservation deteriorates from moderate to poor, and in particular most of the discoasters are heavily overgrown. A major unconformity between the early Miocene (~19.5 m.y.) and early Oligocene (~35.0 m.y.) is based upon the absence of Zones NN1 to NP23. In the lower Oligocene, preservation is somewhat improved, but is poor again in the upper Eocene, where most specimens are overgrown by calcite.

Quaternary

The presence of *Emiliania huxleyi* in Samples 592-1-1, 3–4 cm and 592-1-3, 3–4 cm places these samples in the late Pleistocene *Emiliania huxleyi* Zone (NN21). Sample 592-1,CC, above the last occurrence of *E. ovata* in Sample 592-2-1, 3–4 cm, is placed in the late Pleistocene *Gephyrocapsa oceanica* Zone (NN20). The interval from Samples 592-2-1, 3–4 cm to 592-3-1, 3–4 cm, above the last occurrence of *Calcidiscus macintyrei* in Sample 592-3-2, 2–3 cm, is placed in the upper subzone of the early Pleistocene *E. ovata* Zone (NN19b). The lower subzone of this zone (NN19a) includes Samples 592-3-2, 3–4 cm (the last occurrence of *C. macintyrei*), and 592-3-5, 3–4 cm.

Pliocene

The presence of *Discoaster brouweri* and the absence of *D. pentaradiatrus* in Samples 592-3-6, 3–4 cm to 592-4-1, 3–4 cm places these samples in the late Pliocene *Discoaster brouweri* Zone (NN18). Sample 592-4-2, 3–4 cm includes both *D. brouweri* and *D. pentaradiatus* and is placed in the late Pliocene *D. pentaradiatus* Zone (NN17). The addition of *D. surculus* in Samples 592-4-3, 3–4 cm places the interval from this sample to Sample 592-6-3, 3–4 cm in the late Pliocene *D. surculus* Zone (NN16).

The interval from the last occurrence of *Reticulofenestra pseudoumbilica* in Samples 592-6,CC to 592-8-5, 3–4 cm is placed in the early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). The interval from the last occurrence of *Amaurolithus tricorniculatus* in Sample 592-8,CC to the first occurrence of *D. asymmetricus* in Sample 592-13,CC is placed in the early Pliocene *D. asymmetricus* Zone (NN14).

The boundary between the early Pliocene Zones NN12 and NN13 cannot be determined because *Ceratolithus rugosus* is not present at this site. Therefore the interval from Samples 592-14-1, 3-4 cm to 592-14,CC, above the last occurrence of *D. quinqueramus*, is placed in the combined NN12/NN13 Zone.

Miocene

The co-occurrence of *Amaurolithus primus* and *D. quinqueramus* in Samples 592-15-1, 3-4 cm to 592-17,CC places these samples in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). The lower subzone of this zone (NN11a) includes Samples 592-18-1, 3-4 cm to 592-19-1, 3-4 cm. The interval between the first occurrence of *D. quinqueramus* and the last occurrence of *D. hamatus* (Samples 592-19-3, 3-4 cm to 592-20,CC) is placed in the late Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus*, Samples 592-21-1, 3-4 cm to 592-22,CC, defines the middle Miocene *D. hamatus* Zone (NN9). The first occurrence of *Catinaster coalitus* in Sample 592-23-1, 3-4 cm places this sample in the middle Miocene *Catinaster coalitus* Zone (NN8). The interval below the first occurrence of *C. coalitus*, Sample 592-23-3, 3-4 cm, to the first occurrence of *D. kugleri* in Sample 592-24,CC, is placed in the middle Miocene *D. kugleri* Zone (NN7).

The middle Miocene *D. exilis* Zone (NN6) includes Samples 592-25-1, 3-4 cm to 592-28-1, 3-4 cm, above the last occurrence of *Sphenolithus heteromorphus*. The middle Miocene *Sphenolithus heteromorphus* Zone (NN5) includes Sample 592-28-3, 3-4 cm, the last occurrence of *S. heteromorphus*, to the first occurrence of *D. exilis* in Sample 592-29-3, 3-4 cm. Samples 592-29-5, 3-4 cm to 592-31-3, 3-4 cm, above the last occurrence of *S. belemnos* in Sample 592-31-5, 3-4 cm, are placed in the early Miocene *Helicosphaera ampliaperta* Zone (NN4). The interval from Samples 592-31-5, 3-4 cm to 592-32-3, 3-4 cm, above the last occurrence of *Triquetrorhabdulus carinatus* in Sample 592-32-5, 3-4 cm, is placed in the early Miocene *S. belemnos* Zone (NN3).

An unconformity exists between Samples 592-33-3, 5-6 cm and 70 cm. All of the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1) and possibly part of the overlying *D. druggii* Zone (NN2) as well as all of the late and middle Oligocene Zones (NP23 to NP25) and part of the early Oligocene *H. reticulata* Zone (NP22) are missing.

Oligocene

The interval from Samples 592-33-3, 70 cm to 592-34,CC is placed in the early Oligocene *H. reticulata* Zone (NP22). The early Oligocene *Ericsonia subdisticha* Zone (NP21) includes Samples 592-35-1, 3-4 cm to 592-37-2, 5-6 cm.

Eocene

The last occurrence of *D. saipanensis* in Sample 592-37-2, 33-34 cm and the first occurrence of *Isthmolithus recurvus* in Sample 592-41,CC places this interval in the combined late Eocene *Isthmolithus recurvus*–*S. pseudoradians* Zone (NP19/NP20). Sample 592-40,CC to 591-41,CC contain reworked species from the late middle and early upper Eocene such as *Neococcolithus dubius* and *Chiasmolithus solitus*, similar to the approximate interval at Site 593. The presence of abundant *Zygrhablithus bijugatus* and some *Braarudosphaera bigelowi* in the late Eocene–early Oligocene indicates shallow-water conditions during that interval.

Radiolaria, Diatoms, and Silicoflagellates

In Site 592, Radiolaria are present only in part of the late Eocene. Samples available for radiolarian studies range from Section 592-37-1 to 592-40-5. Well-preserved radiolarian faunas are present in Sections 592-40-4, 59 40-3, 592-40-2, 592-40-1, 592-39-4, and 592-39-3. Very rare specimens are present in Cores 592-37-4 and 59 37-3. Cores 592-37-1 and 592-37-2 contain only some fragments.

As radiolarian assemblages are different in tropical and polar areas, dating of temperate-latitude sediments by the use of either the low-latitude or high-latitude radiolarian biostratigraphy is often unsuccessful. Fortunately, late Eocene radiolarian assemblages from Site 592 are not very different from tropical faunas and thus the classic biostratigraphy of Riedel and Sanfilippo (197) can be used.

Radiolarian abundances were roughly estimated from the density of radiolarians on strewn-slides, from counts of 2000 to 5000 well-preserved shells for each sample.

The classification used in this report is after Riedel (1967) except for the taxonomy of Trissocyclidae and Lophophaenidae, which is from Petrushevskaya (1971). Some new morphotypes need to be described. A large number of morphotypes have been encountered, but only 39 well-known forms are tabulated (see Caulet, this volume).

Only one radiolarian zone is recognized in Site 592: the *Cryptoprora ornata* Zone in Sections 592-39-3 to 592-40-4. The *C. ornata* Zone, top of the former *Thyrsocyrtis bromia* Zone Riedel and Sanfilippo, emended by Maurrasse and Glass (1976) and Saunders et al. (in press), is the uppermost radiolarian zone of the Eocene.

Since no radiolarian forms were found from the *Theocyrtis tuberosa* Zone of early Oligocene age, the Eocene/Oligocene radiolarian boundary cannot be located at Site 592.

Late Eocene radiolarian assemblages from Site 592 are similar to tropical faunas but lack some typical morphotypes like the *Lithocyclia* group. Other tropical species like *Thyrsocyrtis bromia* appear to be rare and restricted to the upper part of the radiolarian zone. However, their skeletons are somewhat different from the tropical forms. Tests of *Cyclampterium*(?) *milowi* are frequent but the test outline is narrower in the mid-latitude assemblages. Some forms like *Lychnocanoma amphitrite* and *Lithapium mitra* are more frequent than in tropical assemblages. As shown by Chen (1975), high-latitude radiolarian assemblages "are similar to but less diverse than the late middle Eocene to late Eocene low-latitude assemblages previously described by Riedel and Sanfilippo (1971) and Foreman (1973)."

Petrushevskaya (1975) reported that Eocene radiolarian faunas from the South Pacific sector of the Southern Ocean (DSDP, Leg 29) are more similar to the Californian Eocene assemblages than those from the Caribbean. This is also the case for Eocene radiolarians from Site 592.

The preservation of the tests is good only in Sections 592-40-2, 592-40-3 and 592-40-4, where the diversity of morphotypes is higher and diatoms are more abundant. In Sample 592-39-3 the siliceous fraction is represented only by broken radiolarian tests. In Samples 592-37-3 and 592-37-4, the number of the forms found is low and their state of preservation poor.

It may be concluded that the deposition of radiolarians and other siliceous microfossils ceased at Site 592 before the very end of the late Eocene and that reworking processes are responsible for the rare latest Eocene siliceous accumulations occurring near the Eocene/Oligocene boundary.

Silicoflagellates have not been found in the Site 592 material.

PALEOMAGNETISM

Sediments from this site were characterized by a thinner and less prominent surficial high-intensity zone and generally very high directional scatter. A magnetic polarity stratigraphy can be traced back to about 3 m.y. ago.

Both the HPC and the XCB cores were subsampled at three specimens per section. Kuster-tool orientation data was obtained for only 25% of the HPC cores recovered. Laboratory NRM and low-field susceptibility measurements have been completed on most specimens. Hole mean statistics are:

Geometric mean intensity (μG)	−0.056
Scalar mean inclination (± s.d.)	−5.8 ±41.9°
Axial dipole inclination	−55.9°
Mean angular difference between repeats	10.2° (20 repeats)

The sediments gave very weak low-field magnetic susceptibilities (less than a few μG/Oe) which were predominantly negative—that is diamagnetic (Table 3). Pure diamagnetic materials do not retain a magnetic remanence. However, in sediments such as these, the diamagnetism of the bulk of the material could easily swamp a weak positive-susceptibility contribution from grains capable of retaining a magnetic remanence.

The usual high-intensity, oxidized zone occurs at the top of the section, but here it was weaker (−0.03 to 1.0 μG) and thinner (~3 m) than at previous sites. Below this zone intensities showed considerable scatter, generally within the range 0.01 to 0.1 μG, which is indicative of very variable conditions of sedimentation. An exception to this rule is a region of higher intensity (~1.0 μG) from Cores 592-29 through 592-32, spanning the early Miocene and the start of the middle Miocene. The onset of this region is gradual, but its termination at the top of Core 592-29 is abrupt. It probably correlates and has a similar origin to the high-intensity zones observed in the middle Miocene at Sites 588 and 593, although it is less pronounced.

Relatively high intensity spikes in Hole 592 are noted in Table 4.

The upper sediments were difficult to subsample without causing distortion. This is reflected in an increase in directional scatter, but is not sufficient to mask the polarity stratigraphy, which could be traced down to the end of the Gauss Chron about 3 m.y. ago (Fig. 9). Be-

Table 3. Magnetic susceptibilities at Site 592.

Core-Section (level in cm)	Depth	Susceptibility
592-1-1, 25	0.25	
		Very weak negative (diamagnetic)
592-29-1, 27	264.45	
		Very weak positive
592-30-1, 25	273.55	
		Very weak negative (diamagnetic)
592-30-6, 25	281.05	
592-31-1, 44	283.34	
		Very weak positive
592-32-4, 77	297.77	
		Very weak negative (diamagnetic)
592-41-6, 75	387.15	

Table 4. Magnetic intensity spikes in Hole 592.

Core-Section (level in cm)	Depth (m)	Intensity (μG)
2-6, 75	12.75	0.264
12-2, 25	102.25	1.754
12-5, 25	106.75	0.876
13-1, 75	110.85	2.449
15-1, 25	129.55	0.236
15-3, 75	133.05	0.260
16-1, 25	139.15	0.302
16-1, 125	140.15	0.355
17-5, 25	154.75	0.921
18-2, 25	159.85	1.042
18-4, 125	163.85	0.291
19-4, 25	172.45	0.368
20-3, 75	181.05	0.490
26-4, 125	240.65	0.981
34-2, 75	315.45	0.580
35-1, 75	322.05	0.452
38-4, 25	354.85	1.480
40-4, 75	374.55	1.027

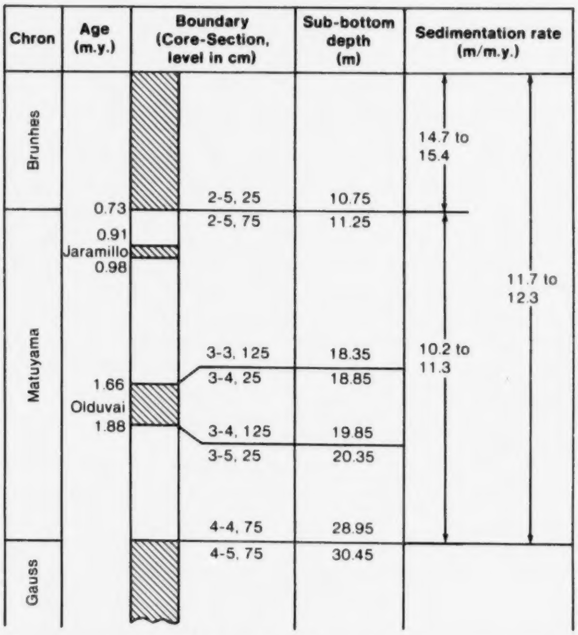


Figure 9. Magnetic polarity stratigraphy for the upper part of Site 592.

low this (apart from the higher-intensity zone just mentioned), directions were more scattered than for previous sites, with a high percentage of intermediate directions. The scatter is particularly bad between 100 and 190 m sub-bottom depth. Since the laboratory measurements were repeatable (mean angle between repeats = 10.2°), this cannot be attributed to instrumental noise and must be an intrinsic property of the sediments. It is not yet known if the scatter can be reduced by AF cleaning.

SEDIMENTATION RATES

Sedimentation rates are calculated as outlined for the previous sites, but the intervals used are subdivided where necessary, especially in the Pliocene and late Miocene (Fig. 10).

The late Eocene sedimentation rate (7.0 m/m.y.; nannoplankton Zones NP19/NP20) in indurated calcareous sediments with trace amounts of siliceous material (radiolarians, sponge spicules, volcanic glass) seems similar to that of the early Oligocene. In the early Oligocene (Zones NP21 and NP22), the sedimentation rate is 19.0 m/m.y. in a calcareous ooze, calculated on the basis of two datum levels.

The sedimentation rate drops in the early to middle Miocene interval (Zones NN2 top to NN7 top) to 13.6 m/m.y. in a foraminifer-bearing nannofossil ooze.

For the late Miocene (nannoplankton Zone NN11) it drops further to 7.5 m/m.y., and then increases again to 24.8 m/m.y. during the early Pliocene. In the late early Pliocene (Zones NN14 and NN15) a major increase of the sedimentation rate occurs, to 92.5 m/m.y., similar to the even higher value at Site 591. In the late Pliocene (Zones NN16 to NN18) it decreases again, and calculated on the basis of four datum levels is 21.2 m/m.y. Finally, in the Quaternary the sedimentation rate is reduced to only 9.8 m/m.y.

Compared with Site 591, there is a considerable drop in the sedimentation rate throughout the Miocene to Recent, although the rate is still high in the late early Pliocene.

SUMMARY AND CONCLUSIONS

Site 592 is located near the southern end of Lord Howe Rise at 36°28.4'S, 165°26.53'E, at a water depth of 1098 m. Although Site 592 (originally SW-2) was assigned as a secondary objective during Leg 90, it was possible to budget two days for drilling at this location. Of particular interest was the determination of calcareous biogenic sedimentation rates during the Neogene to compare and contrast with sites both to the north and south. The coring would also provide another valuable site for the north-south paleoceanographic traverse to study both surface and intermediate water mass changes through the Neogene.

Site 592 is located about 60 km north of Site 207, which was located in an area of thin (360 m) sediment cover overlying a basement high composed of rhyolite. At Site 207, the upper 142 m of sediment cover consists of a thin middle Miocene to Quaternary sequence of foraminifer-nannofossil ooze that is unconformably underlain by siliceous calcareous and calcareous oozes of Eocene age. At Site 207 the Neogene sediments clearly were winnowed, judging from low sedimentation rates and the relatively high proportion of foraminifers. The basement high upon which Site 207 is located focused bottom currents during the Cenozoic.

Since the primary objectives of Leg 90 were related t paleoceanographic history, rather than basement prol lems, a site was chosen in an area of thicker (600 m) se iment cover, but still close to Site 207.

Site 592 consists of one hole cored continuously wit the HPC from 0–234.9 m sub-bottom and then with th XCB from 234.9–388.5 m sub-bottom (Fig. 11). Althoug the hole was cored continuously, recovery is not con plete and decreases below 240 m sub-bottom (middle Mi cene) in the rotary-cored sequence. The core quality generally excellent.

The recovered section consists of a single lithostrat graphic unit that varies from foraminifer-bearing na nofossil ooze (chalk) to nannofossil ooze (chalk) (Fi 11). The section ranges in age from the Quaternary t middle late Eocene (42 m.y. ago). A paleomagnetic po larity stratigraphy has been identified down to the lat Gauss Chron (2.5 m.y.). The lower part of the sectio consists of 83.5 m of Paleogene ooze and chalk ranging in age from the late Eocene to the early Oligocene (35 m.y.). The regional unconformity of the southwest Pacific separates the lower Oligocene sediments from immediately overlying middle lower Miocene sediments 18.5 m.y. old. Calcareous nannofossils are the dominant component (about 75%) throughout the entire sediment sequence. Foraminifers vary from less than 5 to 25%. Beds containing numerous 1–4 cm-sized molluscan (*Ostrea*) fragments occur in the early Oligocene (Section 592-34-3). Noncarbonate components occur only in trace abundances: volcanic glass, pyrite, and clay minerals occur throughout the sequence, whereas quartz, feldspar, and heavy minerals are found only occasionally. Biogenic opal is absent except for the late Quaternary and the Eocene, where radiolarians and sponge spicules occur in trace amounts.

The induration of the sediment varies from a soft ooze at the top of the sequence to a firm ooze near 250 m (earliest middle Miocene), to a chalk near 273.3 m (early Miocene) sub-bottom. The early Oligocene sediment from 305.8–250.0 m, below the regional unconformity, is an ooze. The lower part of this sequence, near 334.4 m, i marked by a chert nodule within a 15-cm thick layer o lithified limestone. The ooze grades downward betwee 350 and 369 m into a firm recrystallized chalk contain ing a high abundance of micrite (5–25%) (latest Eocene)

The section has been divided into five subunits: Sub unit IA represents a veneer (0 to 0.3 m) of pale orange t pinkish gray foraminifer-bearing nannofossil ooze with in the oxidized zone near the seafloor. Subunits IB to II are differentiated by degree of lithification. There is goo planktonic foraminifer preservation in the Neogene an Oligocene, but the benthic foraminifers and the nanno fossils are well preserved only in the late Neogene an Oligocene. Radiolarians are present in small amount only in the Eocene. The biostratigraphic sequences seem to be complete except for that part which is missing in the regional unconformity. Sedimentation rates range from lowest values (7 m/m.y.) in the late Eocene to highest

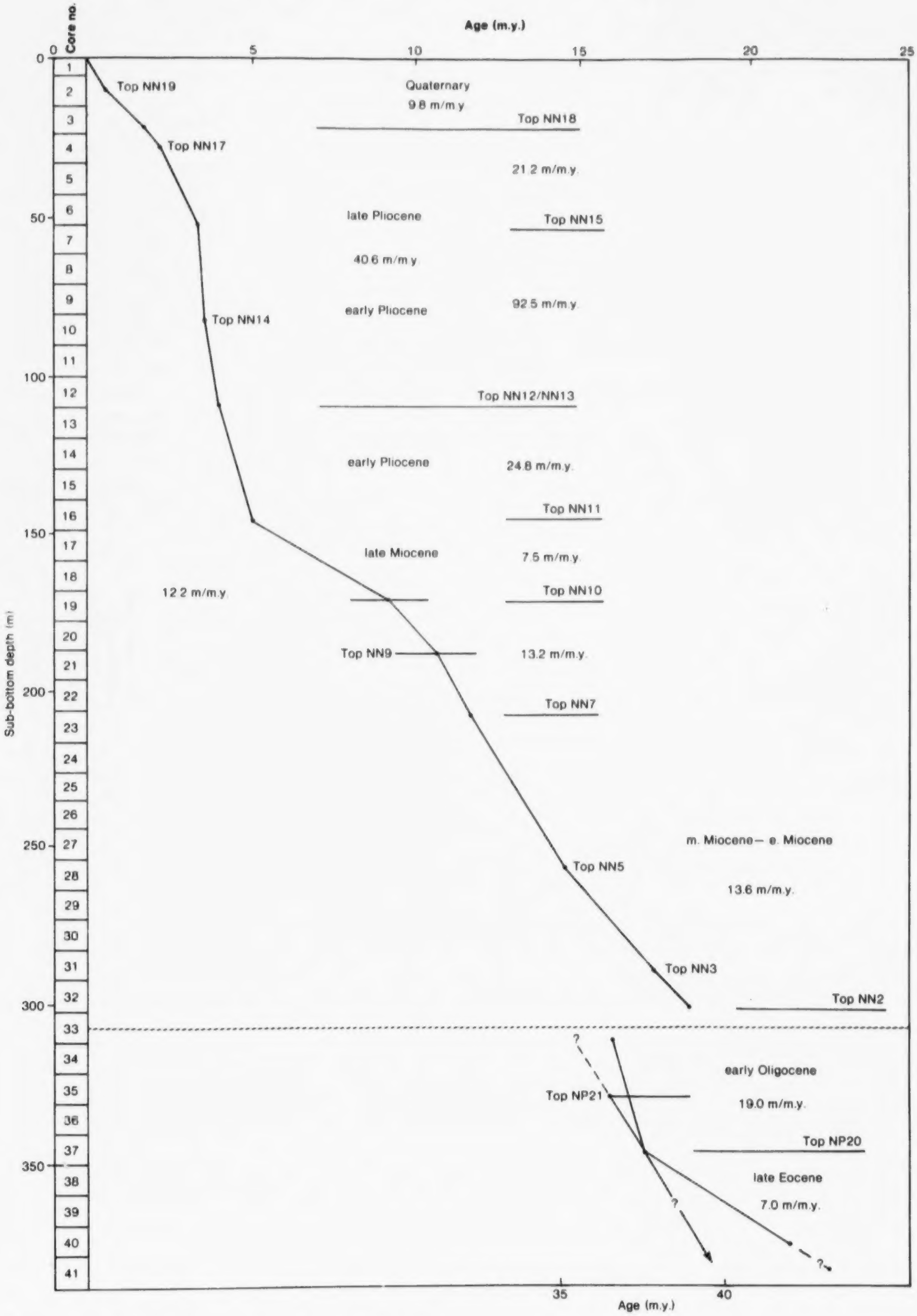


Figure 10. Sedimentation rates and datum levels in Site 592.

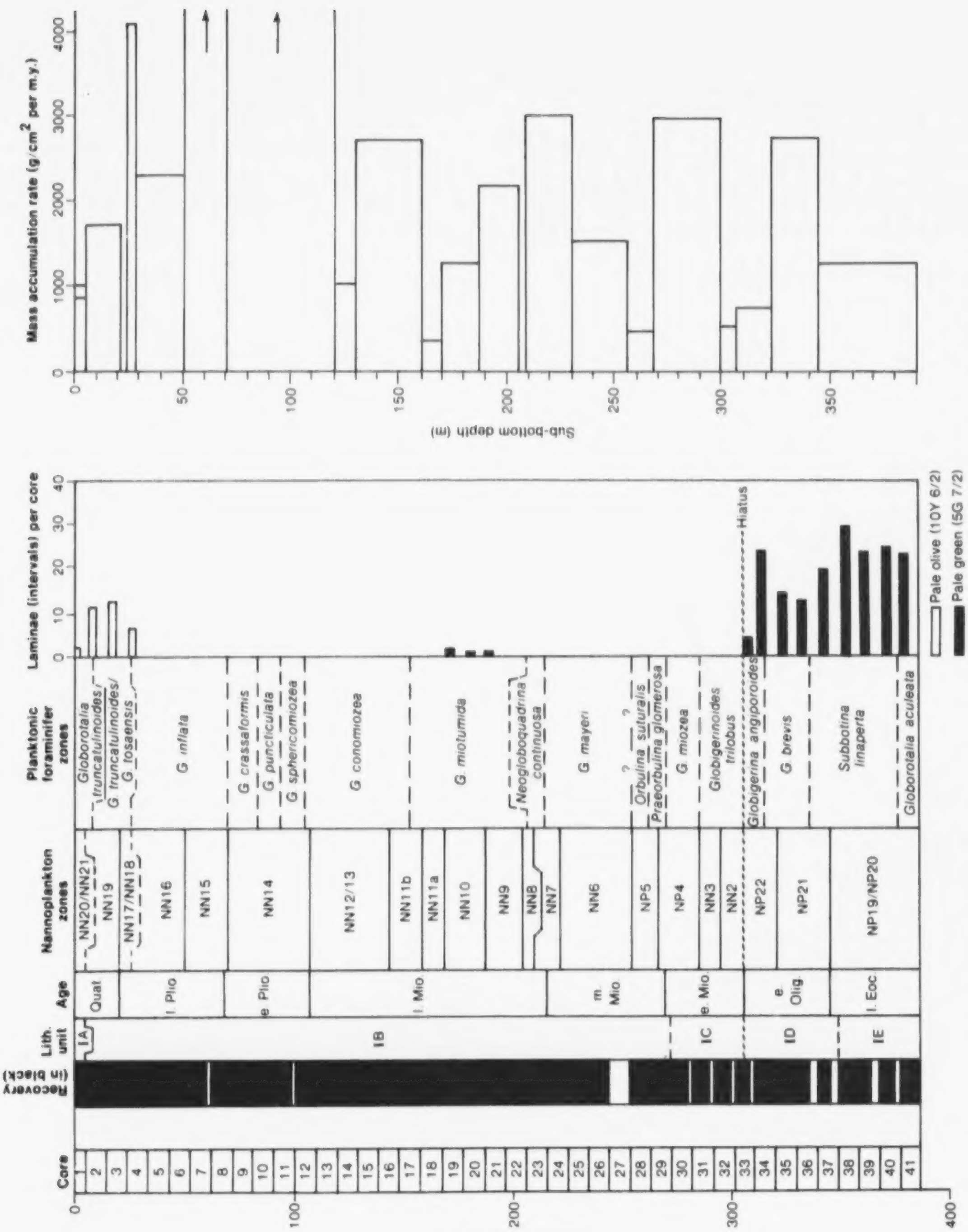


Figure 11. Summary lithology, biostratigraphy, and mass accumulation rates for Site 592. Also shown are ash and altered ash layers.

values (92.5 m/m.y.) in the late early Pliocene. In general, sedimentation rates are much lower at Site 592 than in sites both to the north and south.

Of particular interest at this site is a fine, complete boundary section between the Eocene and the Oligocene in Cores 592-36 and 592-37. The hiatus present in all other South Pacific sites except Site 277 in the subantarctic area south of New Zealand is not found at Site 592. A distinct lithologic change occurs near the level of extinction of *Globigerinatheka index*, which is the foraminifer marker for the boundary in south temperate latitudes. The underlying upper Eocene is represented by nannofossil chalks containing siliceous microfossils such as radiolarians and sponge spicules, whereas the Oligocene is represented by surprisingly soft nannofossil ooze lacking biosiliceous materials.

The extinction of *G. index* is noted in Section 592-36- between 90 and 64 cm. According to the nannoplankton record, the boundary at the extinction of *Discoaster saipanensis* is in Section 592-37-2, between 5–6 and 33– cm. A similar sequence of extinctions for the two taxa was recovered at DSDP Site 277, drilled south of New Zealand (Kennett, Houtz, et al., 1975).

The hiatus separating the early Oligocene from the early Miocene (at 592-33-3, 70 cm) is of considerable interest because it represents the regional unconformity that occurs throughout much of the Tasman Sea (Burns, Andrews, et al., 1973; Kennett et al., 1972). The range which this hiatus represents differs depending upon whether evidence supplied by planktonic foraminifers or calcareous nannofossils is used.

In terms of planktonic foraminiferal zones the unconformity is between the lower part of the *Globigerinoides trilobus* Zone and the upper part of the *Globigerina angiporoides* Zone. The uppermost samples below the unconformity contain both *Globorotalia munda* and *Chiloguembelina cubensis, Globorotaloides testarugosa,* and *Globigerina ampliapertura,* which suggest that this is in the upper part of the *G. angiporoides* Zone. The extinction of *C. cubensis* slightly later in the late Oligocene has been dated by Berggren (1972) at about 30 m.y. ago.

The lowermost lower Miocene above the unconformity is within the *Globigerinoides trilobus* Zone, above the local extinction of *Catapsydrax dissimilis*. An estimated age for this part of the zone is about 18–19 m.y. (Berggren et al., in press). Thus the planktonic foraminifers suggest an age range for the hiatus of about 13 m.y. (i.e., between 31–32 and 18–19 m.y. ago). The calcareous nannofossils, on the other hand suggest a range of 1 .5 m.y. (between NP22 at 35 m.y. ago and NN2 at 1 .5 m.y. ago).

A few pale olive intervals in the upper (Quaternary) and middle parts (early late Miocene) and some grayish green to pale green pockets in the lower part (Paleogene) of the sediment sequence are marked by more common volcanic glass. These intervals may represent episodes of increased volcanic explosivity in the source regions.

Paleoenvironmental History of Site 592

The middle to late Cenozoic sedimentary section at Site 592 represents deposition in a relatively simple pelagic environment near the southern end of Lord Howe Rise. Deposition was in middle bathyal depths that seemed to change little during the Cenozoic. The biogenic sedimentary material is by far dominated by calcareous nannofossils with an admixture of foraminifers. Terrigenous sediments are insignificant in this isolated setting and are restricted to eolian clay and volcanic ash which is either disseminated or occurs as distinct layers. Siliceous biogenic material is almost absent except in the Eocene, where it forms a noticeable fraction. Temperate faunas and floras dominate throughout, with little warm-water influence.

There may have been mild current activity on the seafloor at Site 592 during much of the Cenozoic, since the section is relatively thin and the seismic profiles show a marked thinning of the sequence toward the crest of the Rise at this latitude. Maximum thickness here is only 200 m.

During the late Eocene, calcareous oozes were deposited with trace amounts of radiolarians, sponge spicules, and reworked material. Numerous altered volcanic ash layers indicate a high amount of explosive volcanism in the region. The benthic foraminifers show a high degree of endemism, including forms such as *Vaginulinopsis hochstetteri, Cibicidoides molestus,* and *Rotaliatina sulcigera.*

Deposition continued uninterrupted across the Eocene/Oligocene boundary (foraminifers indicate it to be in 592-36-3, between 90 and 64 cm). There is no sign of any hiatus. Important planktonic microfossils become extinct at or close to the boundary. The extinction of the important marker species *Discoaster saipanensis* occurs slightly earlier (Section 592-37-2) than *Globigerinatheka index* (592-36-3). Siliceous microfossils disappear from the sediments at the same level as the extinction of *G. index.* The replacement of oozes lacking biosiliceous components by those containing such components is very common in the oceanic sedimentary record. This is tied to a major drop of about 2000 m in the calcite compensation depth at the Eocene/Oligocene boundary and related geochemical changes, seemingly at all depths, in the ocean basins. A number of changes in the benthic foraminifers occurred at this time, including the disappearance of *Vaginulinopsis.* Species that become common at the boundary include the spinose stilostomellids, *Valvulineria* sp., *Sphaeroidina bulloides, Cibicidoides lobatulus,* and the bolivinids. Others that become less common are the more ornate cibicidids with limbate sutures.

The change in sedimentation that occurred at the boundary provided a distinctly different diagenetic potential which eventually led to the formation of chalk for the Eocene sediments, whereas those of earliest Oligocene age remained very soft ooze. Sedimentation rates increased to 19 m/m.y. in the early Oligocene, probably as a result of increased productivity and preservation. The early Oligocene assemblages are typically temperate and exhibit low diversity, which is related to cool oceanic temperatures. *Ostrea* (oyster) beds were laid down during one brief interval. Explosive volcanicity continued actively, as in the late Eocene. Early Oligocene benthic foraminifers remained much the same as those of the late Eocene except for larger proportions of *Anomali-*

noides semiteres, Cibicidoides io, Cibicides lobatulus, and the striate bolivinids.

During the middle Cenozoic, bottom currents intensified in the region and created a major hiatus (592-33-3, 70 cm) between lower Oligocene and lower Miocene sediments. This represents a break in sedimentation of 14 to 15.15 m.y. The hiatus represents an extension of the major, regional hiatus of the southwest Pacific (Burns, Andrews, et al., 1973; Kennett et al, 1972). The ages of the major event or events that created the erosion are not known clearly but they are centered in the early to middle Oligocene. Erosion in some areas seems to have commenced at the Eocene/Oligocene boundary and to have continued into the early Miocene. At Site 592, within the Oligocene-early Miocene, erosion did not cut back as far as the Eocene/Oligocene boundary, which was preserved. Kennett et al. (1972) have speculated that the Tasman Sea-Coral Sea area was a major conduit for northward-moving bottom waters until the late Oligocene, at about the time that deep circum-Antarctic circulation began and bottom-water flow was diverted away from the Lord Howe Rise region.

Sedimentation recommenced at Site 592 about 19 m.y. ago in the late early Miocene. By this time, explosive volcanism had virtually disappeared from the immediate region, judging by a near absence of altered volcanic ash layers, except for a few minor, pale green layers in the early late Miocene. Although there was much volcanism in New Zealand during the Neogene, Site 592 is located upwind, with less opportunity for volcanic ash deposition. Sedimentation rates through the early and middle Miocene remained much the same as they had been in the early Oligocene, about 13 m/m.y. However, by the latest Miocene they were reduced to 7.5 m/m.y.

The Neogene benthic foraminifers develop much less endemic characteristics. Most species are known from the broader oceanic sphere. The early Miocene assemblages exhibit increased percentages of robulinids, and during the late Miocene there is a marked increase in *Bolivina anastomosa*. The latest Miocene exhibits an increase in the abundance of miliolids and the spectacular benthic form *Anomalina semipunctata* first appears. These events occur earlier at Site 592 than in sites to the north.

The Pliocene is again marked by much higher sedimentation rates, the highest for this section during the Cenozoic. Early early Pliocene rates are 24.8 m/m.y. Late early Pliocene rates are a remarkable 92.5 m/m.y. and late Pliocene, 21 m/m.y. Volcanic ash layers are absent from the Pliocene sediments.

During the late Pliocene at the *Globorotalia crassaformis/G. inflata* turnover, which is considered to be the time of change to glacial conditions, the faunas change in two ways. First, *Cibicides lobatulus* increases dramatically in abundance and dominates all faunas through the remainder of the Pliocene and Quaternary. The numbers of other cibicidids and of the bolivinids increase markedly also. In addition, there is an increase in the proportion of uvigerinids, and a change in the types of uvigerinids from a *Uvigerina hispida-U. hispido-costata* assemblage below, to one dominated by the *U. perigrina* plexus, including forms tending to *U. mediterranea,* and in one sample, *U. spinulosa*. These morphotypes were not seen at the more northerly sites.

The *U. peregrina* plexus then disappears during the *G. tosaensis* interval, when miliolids again become more common in the benthic faunas; it reappears in the Quaternary (Cores 592-2-1).

The Quaternary, as in a number of other sites, i marked by much lower sedimentation rates of nearly 1 m/m.y. This is perhaps due to increased winnowing whic is related to stimulated oceanic circulation. Several dis tinct, pale olive ash layers probably represent major vol canic events in New Zealand to the east. The Quaternar record terminates with a late Quaternary (0 to 0.3 m pale orange to pinkish gray foraminifer-bearing nanno fossil ooze. This represents the zone of oxidation at th sediment/water interface that occurs at almost all of th sites cored during Leg 90.

REFERENCES

Berggren, W. A., 1972. A Cenozoic time-scale: some implications fo regional geology and paleobiography. *Lethaia*, 5:195.

Berggren, W. A., Kent, D. V., and Van Couvering, J. A., in press. Ne ogene geochronology and chronostratigraphy. *In* Snelling, N. J (Ed.), *Geochronology and the Geologic Time Scale*. Geol. Soc London, Spec. Pap.

Burns, R. E., Andrews, J. E., et al., 1973. *Init. Repts. DSDP*, 21 Washington (U.S. Govt. Printing Office).

Chen, P. H., 1975. Antarctic radiolaria. *In* Hayes, D. E., Frakes, L A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 437–514.

Foreman, H. P., 1973. Radiolaria of Leg 10 with systematics and ranges for the families Amphicyndacidae, Artostrobiidae and Theoperidae. *In* Worzel, J. L., Bryant, W., et al., *Init. Repts. DSDP*, 10: Washington (U.S. Govt. Printing Office), 407–474.

Jenkins, D. G., 1974. Initiation of the proto circum-Antarctic current. *Nature*, 252:371.

Kennett, J. P., Burns, R. E., Andrews, J. E., Churkin, M., Jr., Davies, T. A., Dumitricâ, P., Edwards, A. R., Galehouse, J. S., Packham, G. H., and van der Lingen, G. J., 1972. Australian–Antarctic continental drift, paleocirculation changes and Oligocene deep-sea erosion. *Nature* (*Phys. Sci.*), 239(91):51–55.

Kennett, J. P., Houtz, R. E., et al., 1975. *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office),

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports, Scripps Institution of Oceanography, La Jolla California.

Maurasse, F., and Glass, B., 1976. Radiolarian stratigraphy and North American microtektites in Caribbean RC9-58: Implications concerning late Eocene radiolarian chronology and the age of the Eocene/Oligocene boundary. *Publ. VII Conf. Géol. Caraibes (30 Juin au 12 Juillet 1974):* Cayenne, pp. 205–212.

Petrushevskaya, M. G., 1971. Radiolarians of the ocean: reports o the Soviet expeditions. *Explorations of the Fauna of the Seas* (Vol 17): Leningrad (Izd. Nauka).

________, 1975. Cenozoic radiolarians of the Antarctic, Leg 29, DSD *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP,* 29: Wash ington (U.S. Govt. Printing Office), 541–674.

Riedel, W. R., 1967. Some new families of Radiolaria. *Proc. Geo Soc. London*, 1640:148–149.

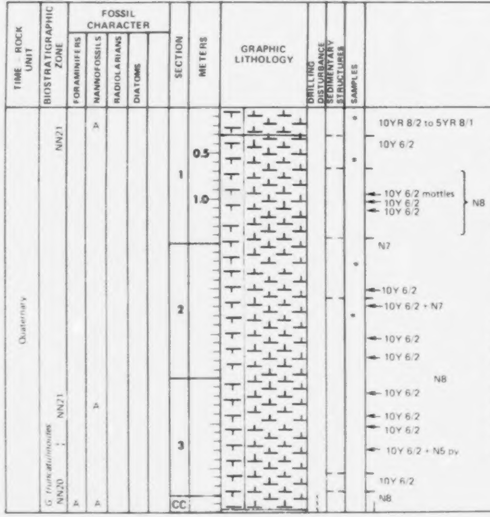
Riedel, W. R., and Sanfilippo, A., 1971. Cenozoic Radiolaria fro the western tropical Pacific, DSDP Leg 7. *In* Winterer, E. L., Ri del, W. R., et al., *Init. Repts. DSDP*, 7, Pt. 2: Washington (U. Govt. Printing Office),1529–1672.

Riedel, W. R., and Sanfilippo, A., 1977. Cainozoic Radiolaria. Ramsey, A. T. S (Ed.), *Oceanic Micropaleontology* (Vol. 2): Lo don (Academic Press), 847–912.

Saunders, J., Perch-Nielsen, K., Sanfilippo, A., and Riedel, W. R., i press. Biostratigraphy of the Eocene to early Oligocene sections Bathcliff Barbados. *Micropaleontology*.

Date of Acceptance: 1 December 1983

SITE 592 HOLE CORE 1 CORED INTERVAL 0.0–4.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21
NN21
G. truncatulinoides
NN20
A
A
A
A
1
2
3
CC
0.5
1.0
10YR 8/2 to 5YR 8/1
10Y 6/2
10Y 6/2 mottles
10Y 6/2
10Y 6/2
N8
N7
10Y 6/2
10Y 6/2 + N7
10Y 6/2
10Y 6/2
N8
10Y 6/2
10Y 6/2
10Y 6/2
10Y 6/2 + N5 py
10Y 6/2
N8

LITHOLOGIC DESCRIPTION

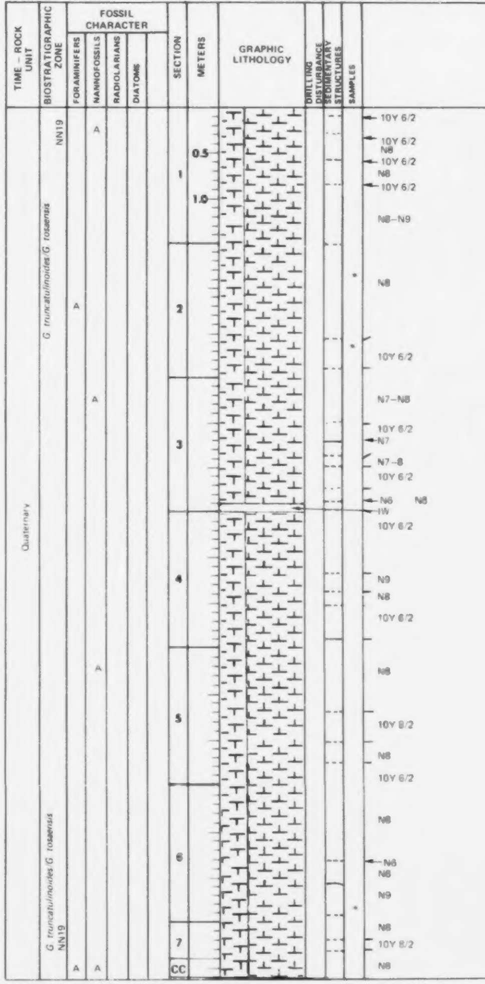
FORAMINIFER-BEARING (20%) NANNOFOSSIL OOZE, very pale orange (10YR 8/2) to pinkish gray (5YR 8/1) soft, massive, oxidized subunit.

FORAMINIFER-BEARING (5–20%) NANNOFOSSIL OOZE, alternating subdominant pale olive (10Y 6/2) and dominant light gray (N7) to very light gray (N8) units, soft, massive with occasional pale olive (10Y 6/2) burrow mottles and medium gray (N5) pyrite streaks, diffuse contacts with host ooze.

SMEAR SLIDE SUMMARY

	1, 8	1, 55	2, 22	2, 79
	D	D	D	D
Texture:				
Silt	A	A	A	A
Clay	D	D	D	D
Composition:				
Quartz	T	–	–	–
Volcanic glass	T–	–	T	–
Foraminifers	C	C	C	C
Calc. nannofossils	D	D	D	D
Diatoms	T	–	–	–
Radiolarians	T	–	T	–
Sponge spicules	T	–	–	–
Other	T	–	T	T

SITE 592 HOLE CORE 2 CORED INTERVAL 4.5–14.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19
G. truncatulinoides/G. tosaensis
G. truncatulinoides/G. tosaensis
NN19
A
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
10Y 6/2
10Y 6/2
N8
10Y 6/2
N8
10Y 6/2
N8–N9
N8
10Y 6/2
N7–N8
10Y 6/2
N7
N7–8
10Y 6/2
N6
IW
N8
10Y 6/2
N9
N8
10Y 6/2
N8
10Y 6/2
N8
10Y 6/2
N8
N6
N8
N9
N8
10Y 6/2
N8

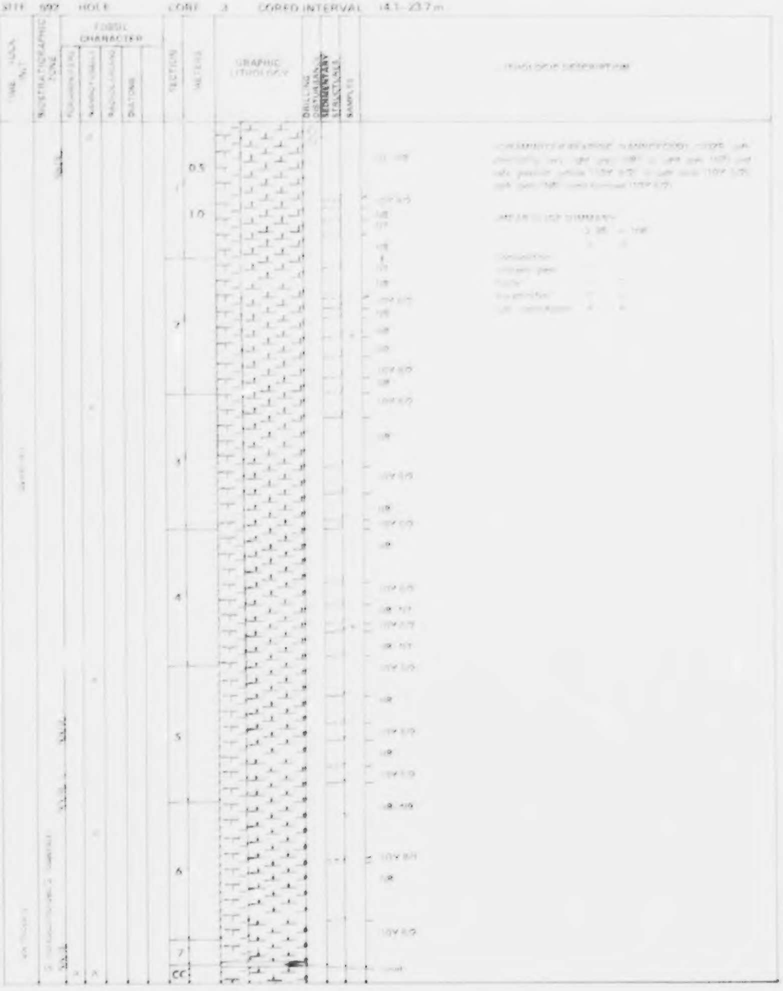
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) and white (N9) to pale olive (10Y 6/2), contacts gradational, iron sulfide blebs and streaks (N6); in the pale olive parts more volcanic ash (1–5%); white (N9) part in Section 6 ← NANNOFOSSIL OOZE.

SMEAR SLIDE SUMMARY

	2, 35	2, 103	6, 122
	D	D	D
Composition:			
Volcanic glass	T	R	R
Pyrite	–	T	T
Foraminifers	C	C	R
Calc. nannofossils	A	A	A
Other	–	–	C

SITE 592 HOLE CORE 3 CORED INTERVAL 14.1–23.7 m



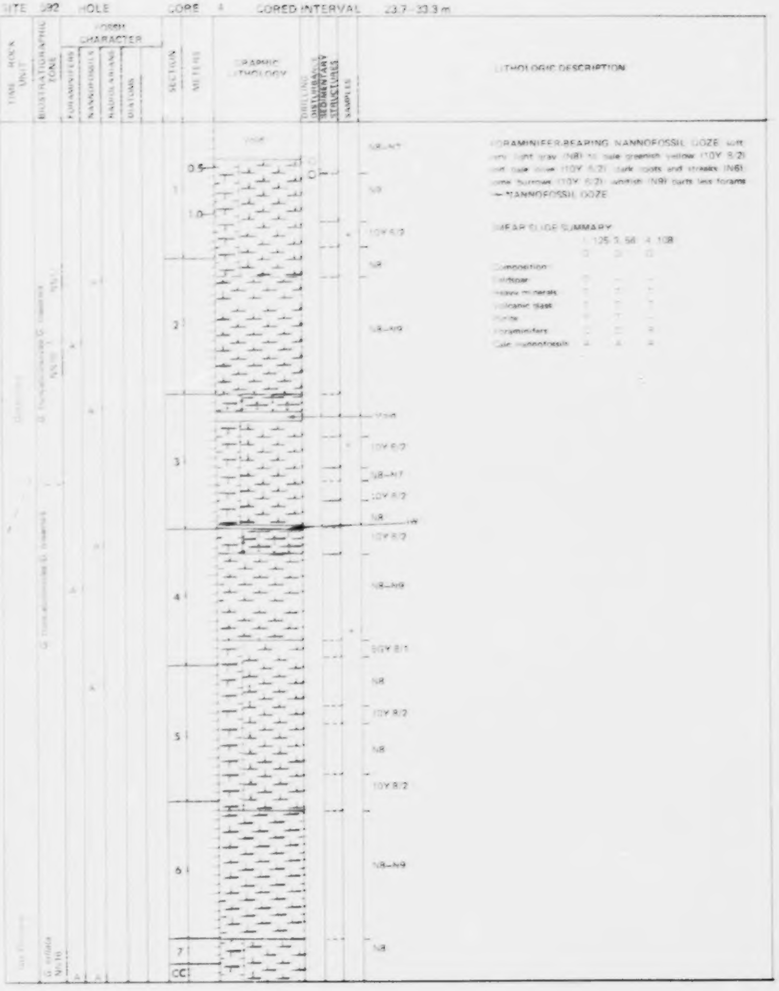
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, [illegible]

SMEAR SLIDE SUMMARY

[illegible]

SITE 592 HOLE CORE 4 CORED INTERVAL 23.7–33.3 m



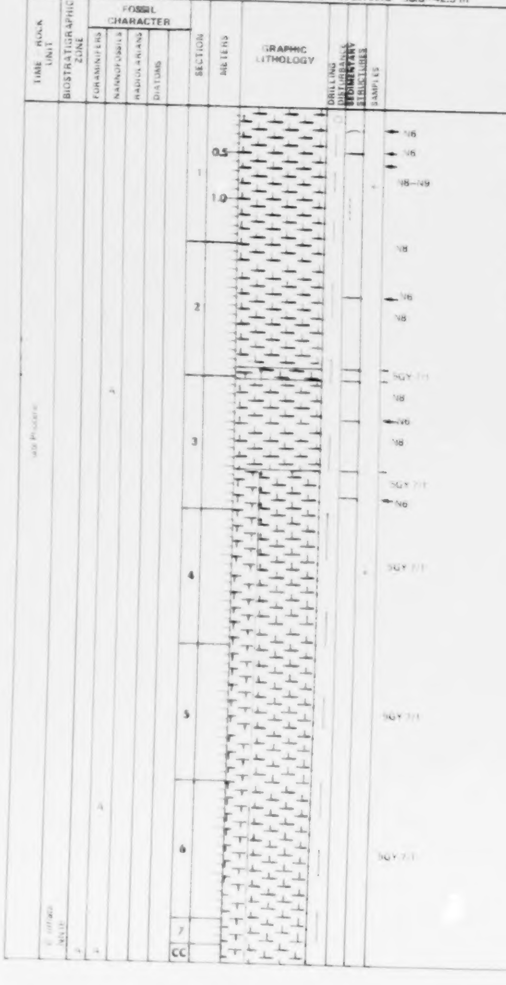
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) to pale greenish yellow (10Y 8/2) and pale olive (10Y 6/2), dark spots and streaks (N6), some burrows (10Y 6/2), whitish (N9) parts less forams → NANNOFOSSIL OOZE

SMEAR SLIDE SUMMARY

	1, 125	3, 56	4, 108
	D	D	D
Composition:			
Feldspar	[illegible]	—	—
Heavy minerals	[illegible]	[illegible]	[illegible]
Volcanic glass	[illegible]	[illegible]	[illegible]
Pyrite	[illegible]	[illegible]	—
Foraminifers	[illegible]	[illegible]	[illegible]
Calc. nannofossils	A	A	A

SITE 592 HOLE CORE 5 CORED INTERVAL 33.3–42.9 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
0.5
1.0
1
2
3
4
5
6
7
CC
N6
N6
N8–N9
N8
N6
N8
5GY 7/1
N8
N6
N8
5GY 7/1
N6
5GY 7/1
5GY 7/1
5GY 7/1
NN16
A
A

LITHOLOGIC DESCRIPTION

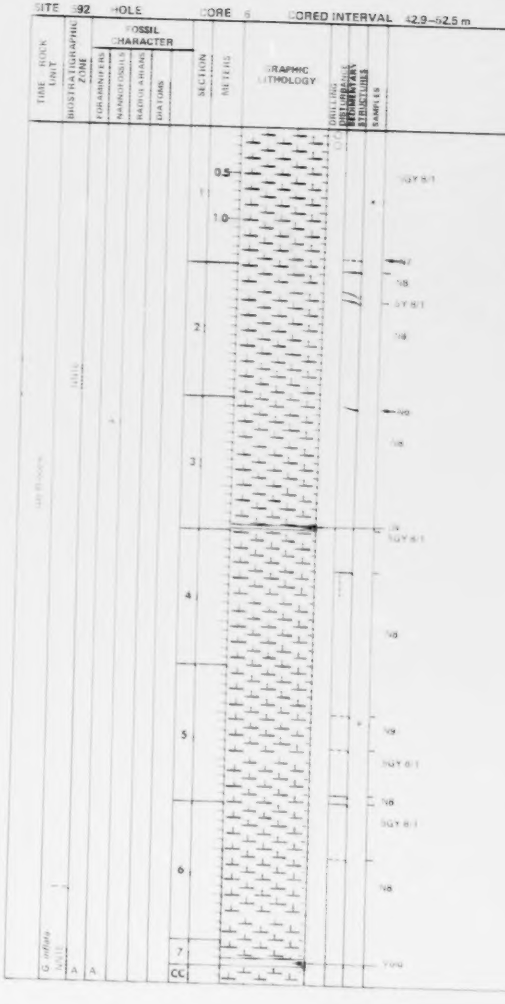
NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), dark (N6) streaks, some pale olive (10Y 6/2) burrows.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, homogeneous, light greenish gray (5GY 7/1), some pale olive (10Y 6/2) burrows.

SMEAR SLIDE SUMMARY:

	1, 82	4, 64
	D	D
Composition:		
Volcanic glass	[illegible]	[illegible]
Pyrite	T	T
Foraminifers	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]

SITE 592 HOLE CORE 6 CORED INTERVAL 42.9–52.5 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
0.5
1.0
1
2
3
4
5
6
7
CC
5GY 8/1
N7
N8
5GY 8/1
N8
N6
N8
N8
5GY 8/1
N8
N9
5GY 8/1
N8
5GY 8/1
N8
G. inflata
NN16
A
A

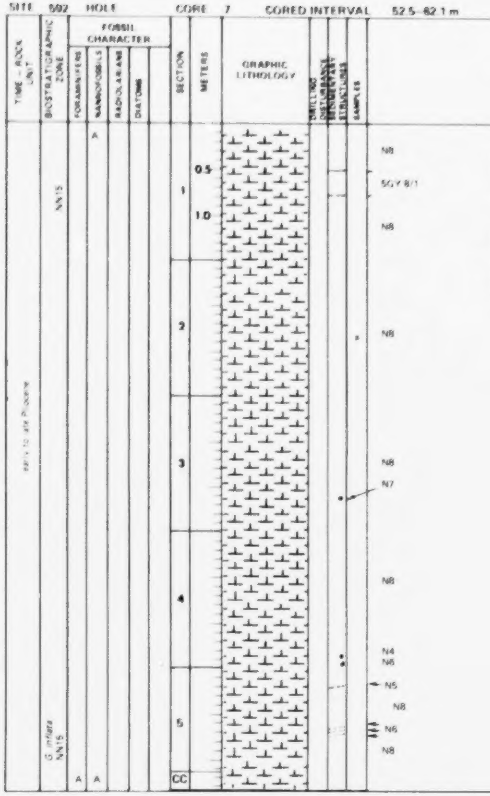
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1), homogeneous. Some dark streaks (N7).

SMEAR SLIDE SUMMARY:

	1, 80	5, 60
	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]

SITE 592 HOLE CORE 7 CORED INTERVAL 52.5–62.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early to late Pliocene
NN15
G. inflata
NN15
A
A A
0.5
1.0
1
2
3
4
5
CC
N8
5GY 8/1
N8
N8
N8
N7
N8
N4
N6
N5
N8
N6
N8

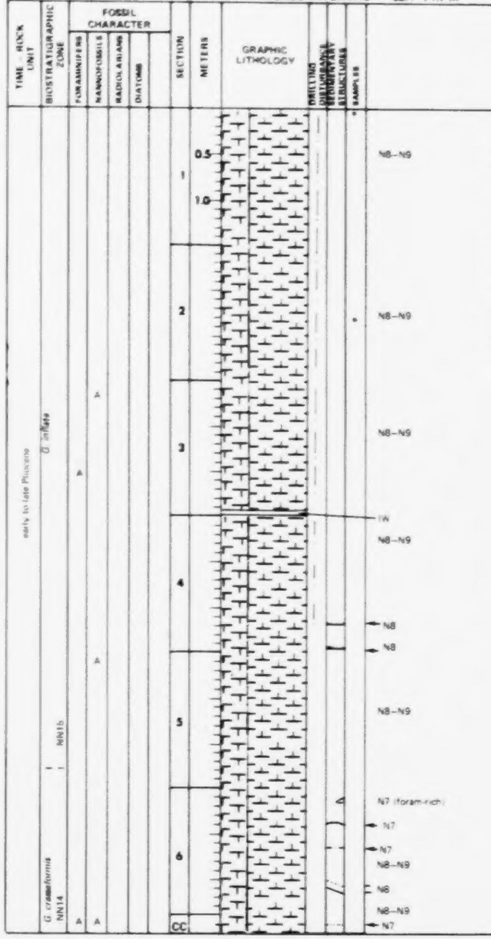
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, some dark (N7–N8) spots and streaks.

SMEAR SLIDE SUMMARY

	2, 86
	D
Composition:	
Volcanic glass	R
Pyrite	T
Foraminifers	R
Calc. nannofossils	A

SITE 592 HOLE CORE 8 CORED INTERVAL 62.1–71.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early to late Pliocene
G. inflata
NN15
G. crassaformis
NN14
A
A
A
A A
0.5
1.0
1
2
3
4
5
6
CC
N8–N9
N8–N9
N8–N9
IW
N8–N9
N8
N8
N8–N9
N7 (foram-rich)
N7
N7
N8–N9
N8
N8–N9
N7

LITHOLOGIC DESCRIPTION

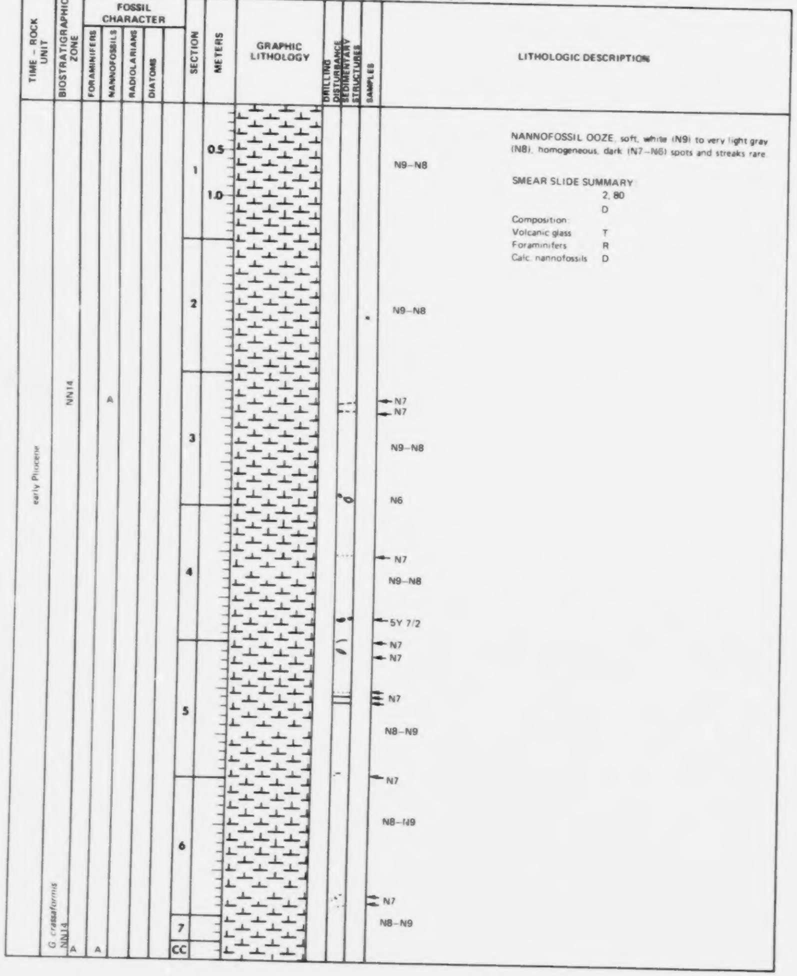
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous, some dark (N6–N7) spots and streaks.

SMEAR SLIDE SUMMARY

	2, 81	1, 0[a]
	D	M
Composition:		
Quartz	–	T
Heavy minerals	T	–
Clay	–	A
Volcanic glass	T	C
Foraminifers	C	–
Calc. nannofossils	A	–

[a] Insoluble residue

SITE 592 HOLE CORE 9 CORED INTERVAL 71.7–81.3 m

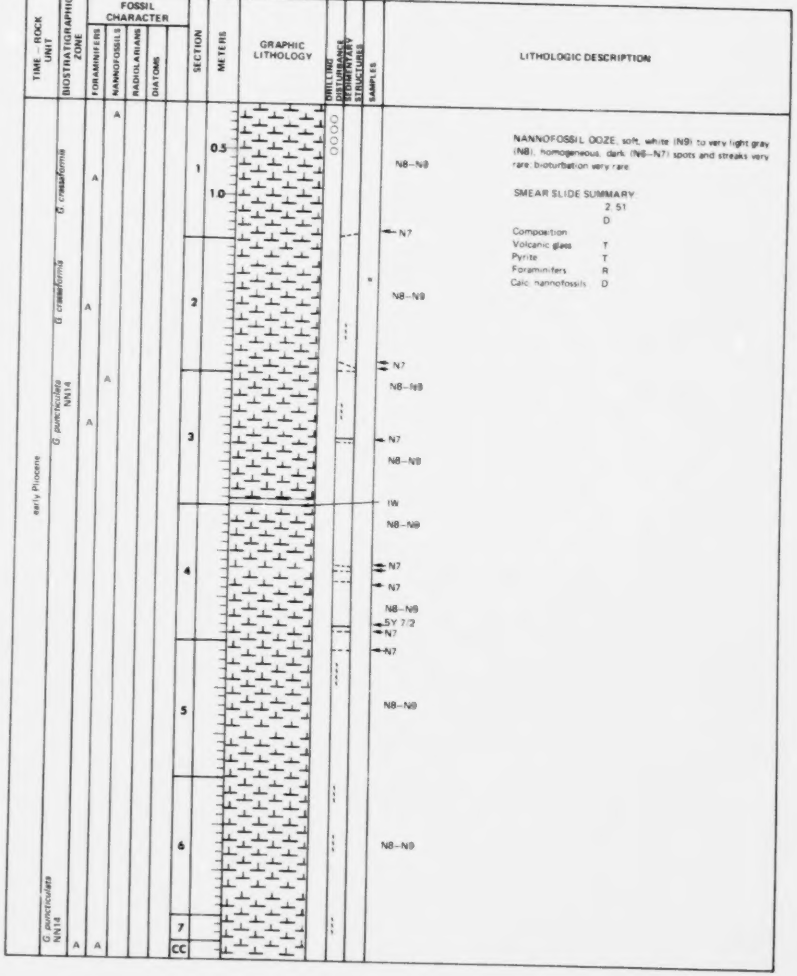

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN14
G. crassaformis
NN14
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9–N8
N9–N8
N7
N7
N9–N8
N6
N7
N9–N8
5Y 7/2
N7
N7
N7
N8–N9
N7
N8–N9
N7
N8–N9

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous, dark (N7–N6) spots and streaks rare.

SMEAR SLIDE SUMMARY

	2, 80
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

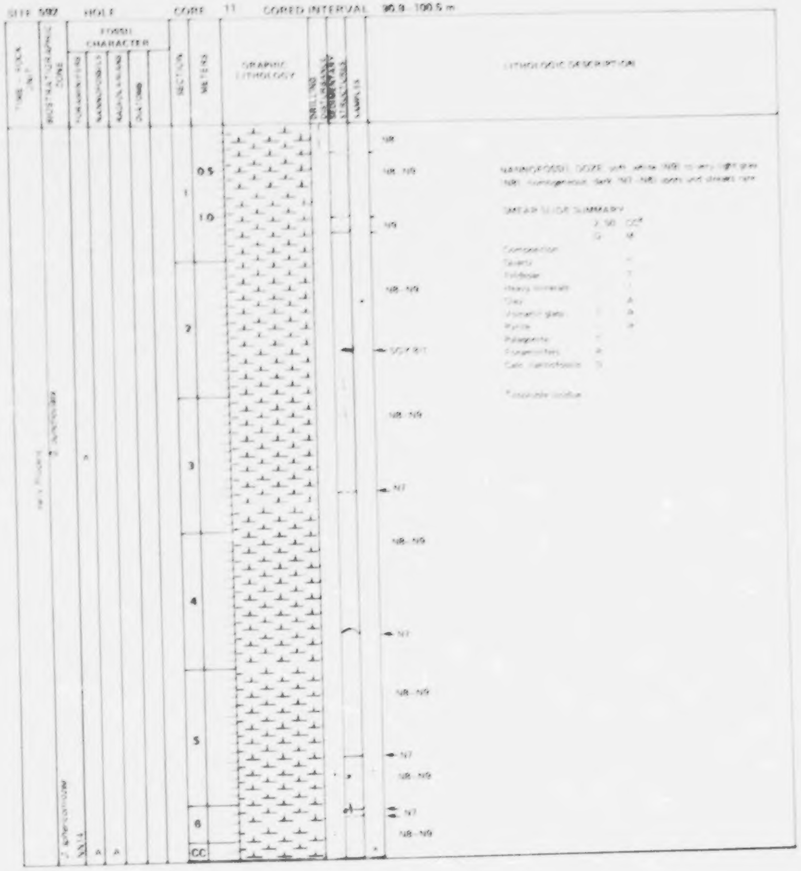
SITE 592 HOLE CORE 10 CORED INTERVAL 81.3–90.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. crassaformis
G. crassaformis
G. puncticulata
NN14
G. puncticulata
NN14
A
A
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8–N9
N7
N8–N9
N7
N8–N9
N7
N8–N9
IW
N8–N9
N7
N7
N8–N9
5Y 7/2
N7
N7
N8–N9
N8–N9

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous, dark (N8–N7) spots and streaks very rare; bioturbation very rare.

SMEAR SLIDE SUMMARY

	2, 51
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

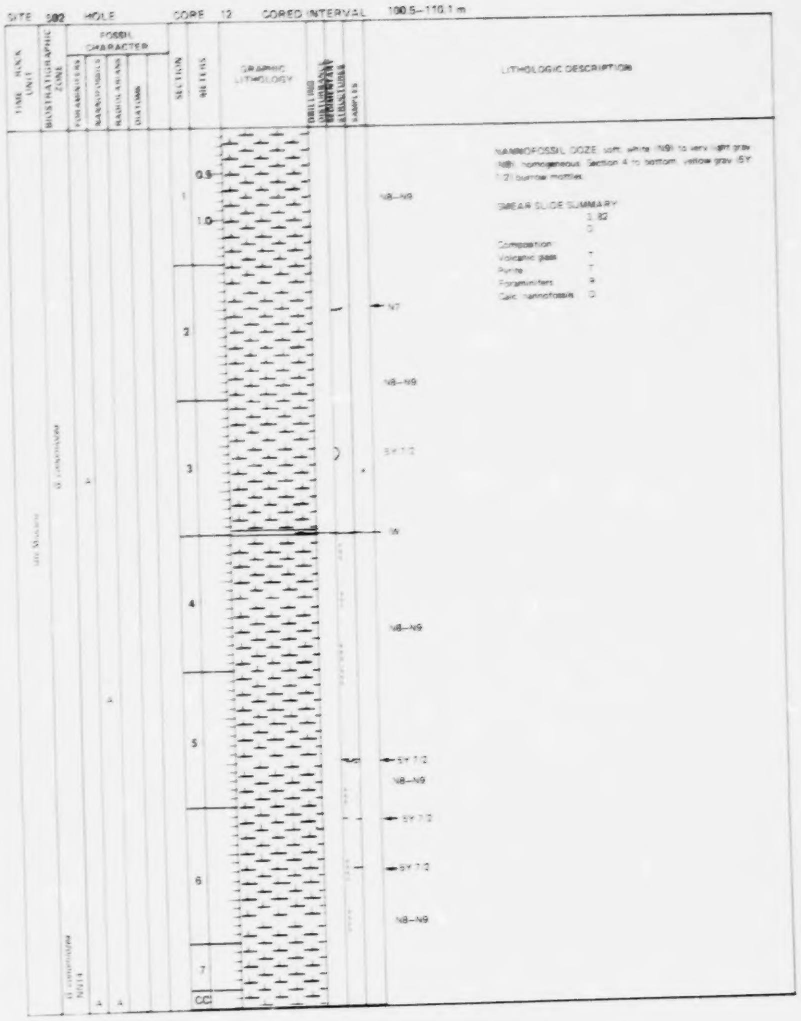

SITE 592 HOLE CORE 11 CORED INTERVAL 90.9–100.5 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
4
5
6
CC
N8
N8–N9
N9
N8–N9
5GY 8/1
N8–N9
N7
N8–N9
N7
N8–N9
N7
N8–N9
N7
N8–N9
A
A
A
NN14

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous. Dark (N7–N8) spots and streaks rare.

SMEAR SLIDE SUMMARY

	2, 90	CC*
	D	M
Composition:		
Quartz		C
Feldspar		T
Heavy minerals		T
Clay		A
Volcanic glass	T	A
Pyrite		R
Palagonite	T	
Foraminifers	R	
Calc. nannofossils	D	

*Insoluble residue

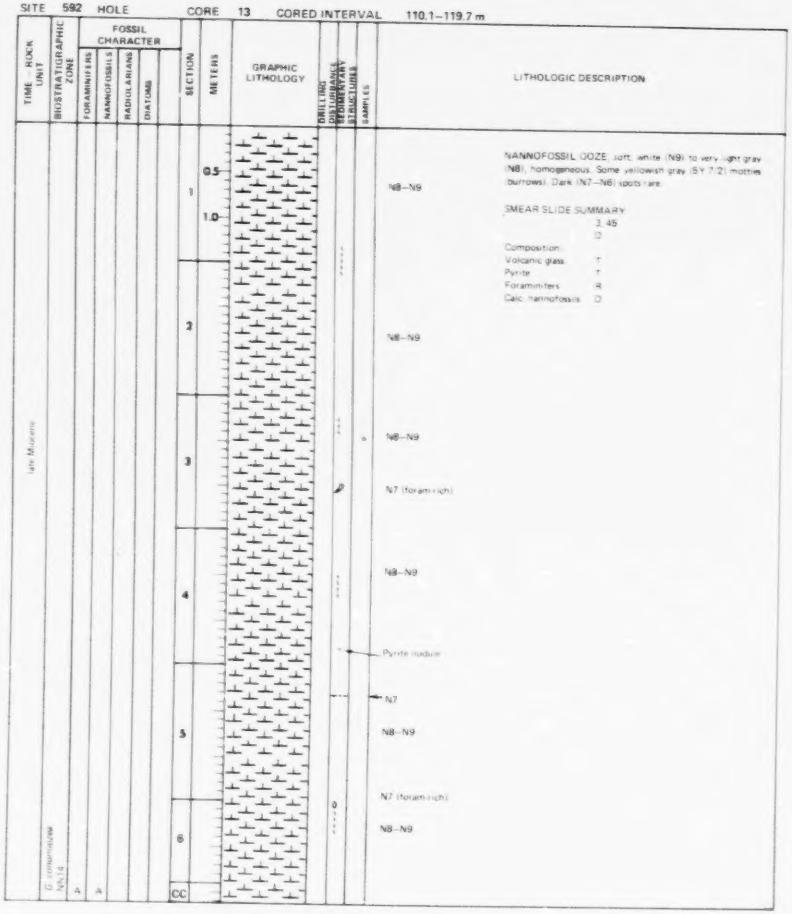

SITE 592 HOLE CORE 12 CORED INTERVAL 100.5–110.1 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
0.5
1.0
1
2
3
4
5
6
7
CC
N8–N9
N7
N8–N9
5Y 7/2
IW
N8–N9
5Y 7/2
N8–N9
5Y 7/2
5Y 7/2
N8–N9
A
A
A
A
NN14

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous. Section 4 to bottom, yellow gray (5Y 7/2) burrow mottles.

SMEAR SLIDE SUMMARY

	3, 82
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 592 HOLE CORE 13 CORED INTERVAL 110.1–119.7 m

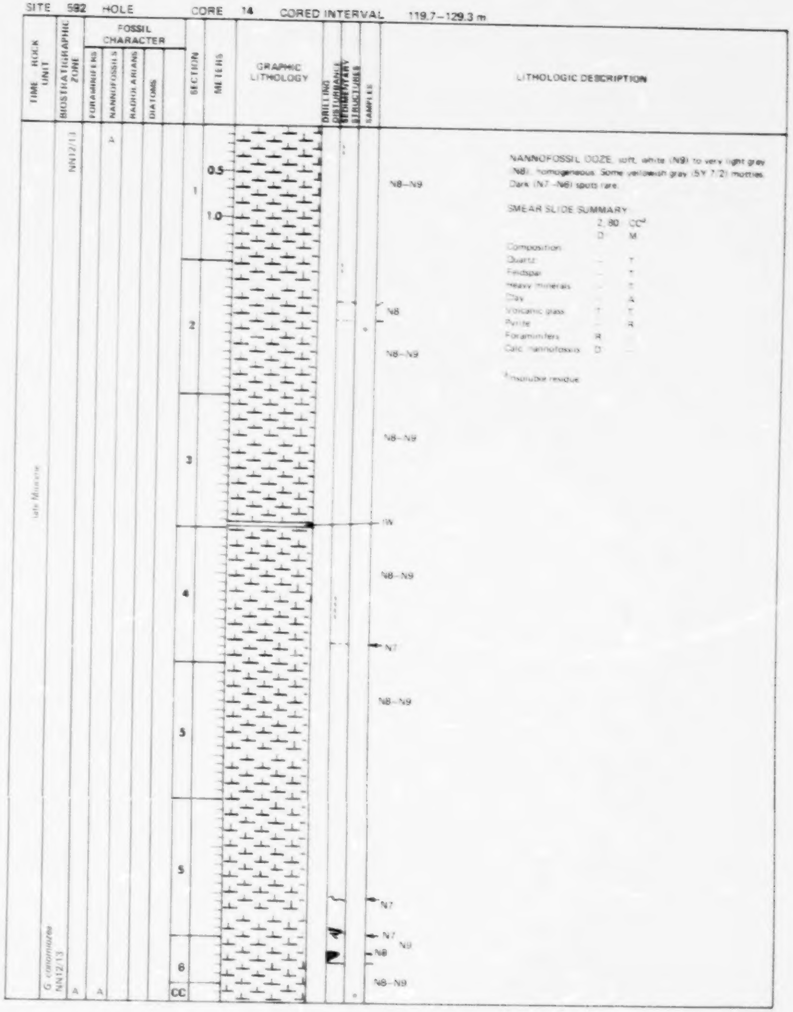

TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. conomiozea
NN14
A
A
0.5
1.0
1
2
3
4
5
6
CC
N8–N9
N8–N9
N8–N9
N7 (foram-rich)
N8–N9
Pyrite nodule
N7
N8–N9
N7 (foram-rich)
N8–N9

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous. Some yellowish gray (5Y 7/2) mottles (burrows). Dark (N7–N6) spots rare.

SMEAR SLIDE SUMMARY

	3, 45
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 592 HOLE CORE 14 CORED INTERVAL 119.7–129.3 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN12/13
A
G. conomiozea
NN12/13
A
A
0.5
1.0
1
2
3
4
5
5
6
CC
N8–N9
N8
N8–N9
N8–N9
IW
N8–N9
N7
N8–N9
N7
N7
N9
N8
N8–N9

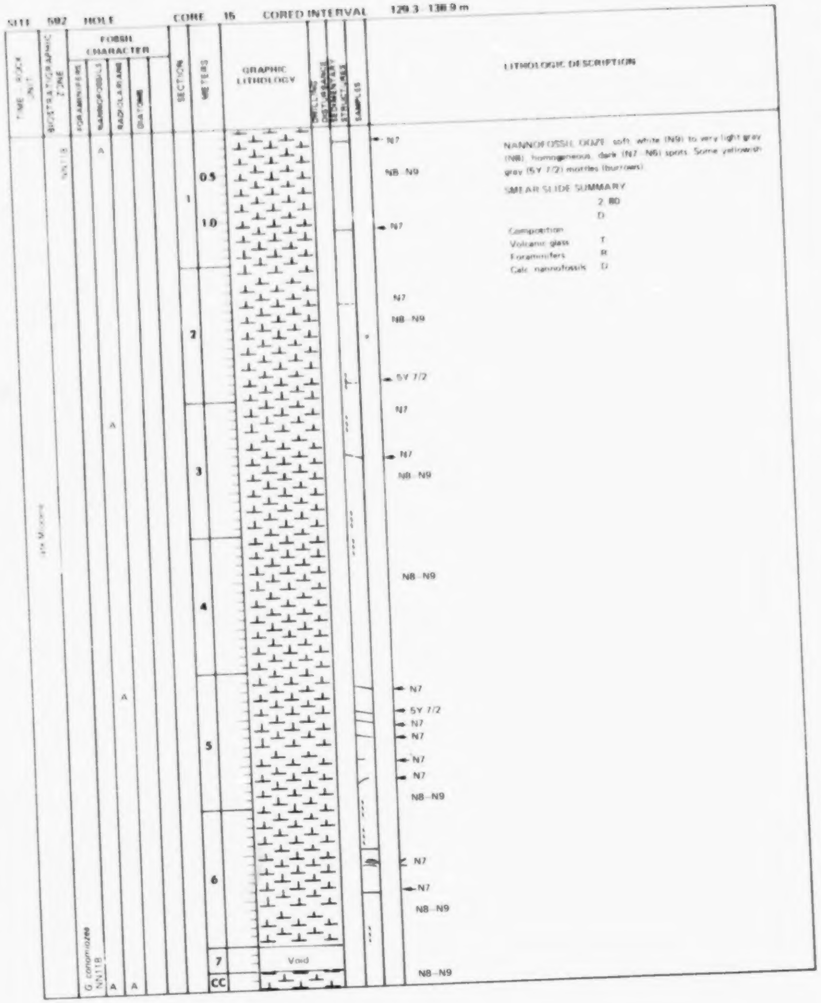
NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous. Some yellowish gray (5Y 7/2) mottles. Dark (N7–N6) spots rare.

SMEAR SLIDE SUMMARY

	2, 80	CC[a]
	D	M
Composition:		
Quartz	–	T
Feldspar	–	T
Heavy minerals	–	T
Clay	–	A
Volcanic glass	T	T
Pyrite	–	R
Foraminifers	R	–
Calc. nannofossils	D	–

[a] Insoluble residue.

SITE 592 HOLE CORE 15 CORED INTERVAL 129.3–138.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
G. conomiozea
NN11B
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7
N8–N9
N7
N7
N8–N9
5Y 7/2
N7
N7
N8–N9
N8–N9
N7
5Y 7/2
N7
N7
N7
N7
N8–N9
N7
N7
N8–N9
N8–N9

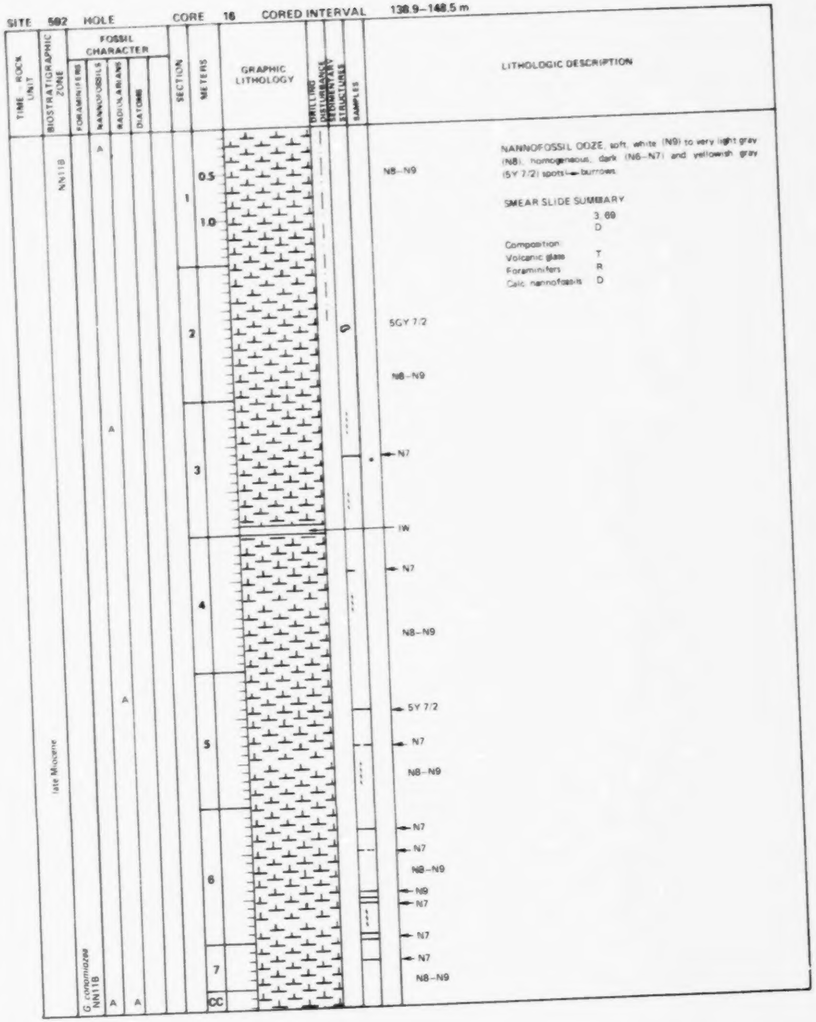
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous, dark (N7–N6) spots. Some yellowish gray (5Y 7/2) mottles (burrows).

SMEAR SLIDE SUMMARY

	2, 80
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 592 HOLE CORE 16 CORED INTERVAL 138.9–148.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11B
G. conomiozea
NN11B
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8–N9
5GY 7/2
N8–N9
N7
IW
N7
N8–N9
5Y 7/2
N7
N8–N9
N7
N7
N8–N9
N9
N7
N7
N7
N8–N9

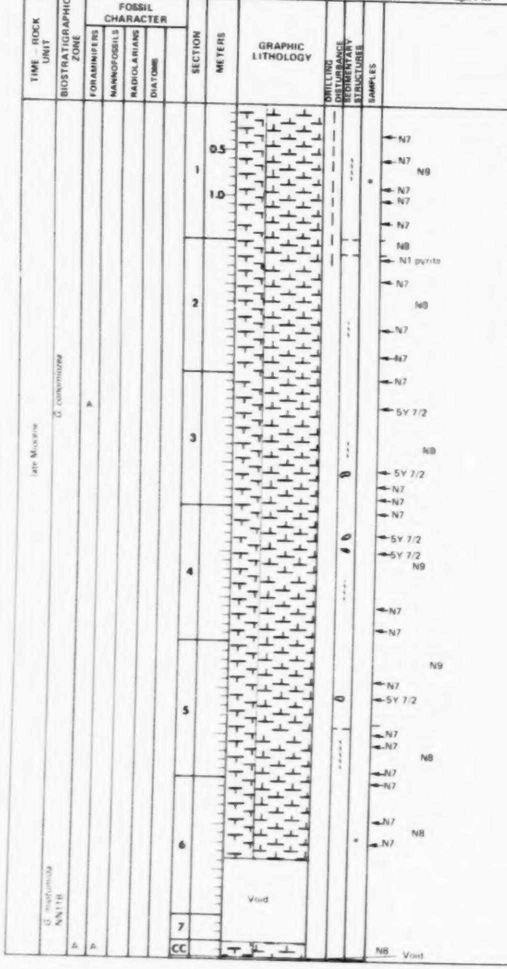
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), homogeneous, dark (N6–N7) and yellowish gray (5Y 7/2) spots←burrows.

SMEAR SLIDE SUMMARY

	3, 69
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 592 HOLE CORE 17 CORED INTERVAL 148.5–158.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
G. miotumida NN11B
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7
N7
N9
N7
N7
N7
N8
N1 pyrite
N7
N8
N7
N7
N7
5Y 7/2
N8
5Y 7/2
N7
N7
N7
5Y 7/2
5Y 7/2
N9
N7
N7
N9
N7
5Y 7/2
N7
N7
N8
N7
N7
N7
N8
N7
N8
Void

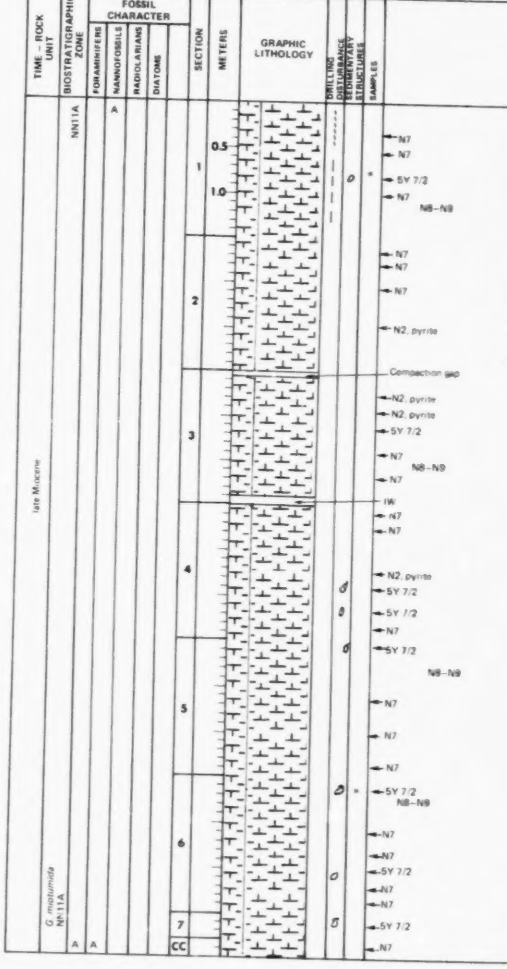
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (5–10%) NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), with occasional light gray (N7) streaks, blebs and halos of pyritized ooze, as well as rare yellowish gray (5Y 7/2) burrow mottles, all with diffuse boundaries.

SMEAR SLIDE SUMMARY

	1, 81 D	6, 68 D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	–	T
Foraminifers	C	C
Calc. nannofossils	D	D
Radiolarians	T	–

SITE 592 HOLE CORE 18 CORED INTERVAL 158.1–167.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11A
G. miotumida NN11A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N7
5Y 7/2
N7
N8–N9
N7
N7
N7
N2, pyrite
Compaction gap
N2, pyrite
N2, pyrite
5Y 7/2
N7
N8–N9
N7
IW
N7
N7
N2, pyrite
5Y 7/2
5Y 7/2
N7
5Y 7/2
N8–N9
N7
N7
N7
5Y 7/2
N8–N9
N7
N7
5Y 7/2
N7
N7
5Y 7/2
N7

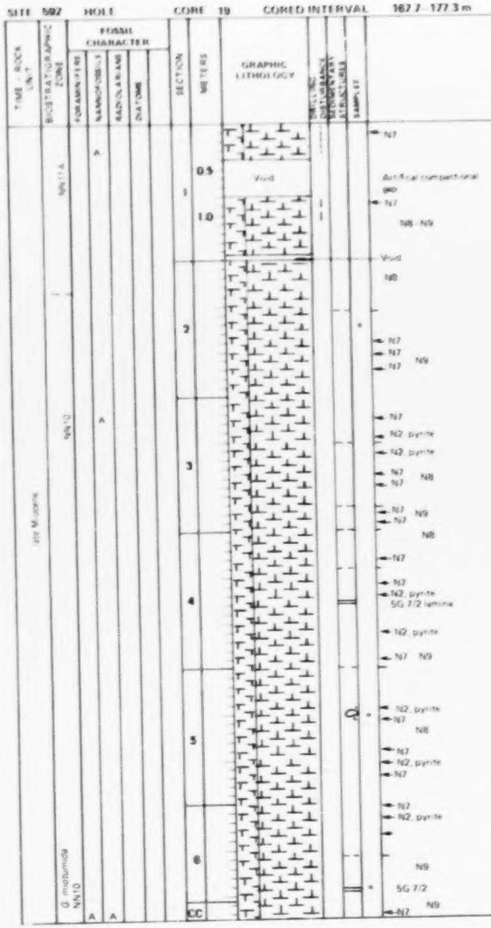
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (≥ 5%) NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), massive with occasional yellowish gray (5Y 7/2) burrow mottles and pyritized (N7 to 5P 4/2) blebs and streaks, all having diffuse contacts with host ooze. Yellowish gray burrows contain more foraminifers (10–15%).

SMEAR SLIDE SUMMARY

	1, 80 D	6, 18 M
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	–	T
Pyrite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 19 CORED INTERVAL 167.7–177.3 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11A
NN10
G. miotumida
NN10
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
Void
N7
Artificial compactional gap
N7
N8–N9
Void
N8
N7
N7
N7 N9
N7
N2 pyrite
N2 pyrite
N7 N8
N7
N7 N9
N7
N8
N7
N2
N2 pyrite
5G 7/2 lamina
N2 pyrite
N7 N9
N2 pyrite
N7
N8
N7
N2 pyrite
N7
N7
N2 pyrite
N9
5G 7/2
N7 N9

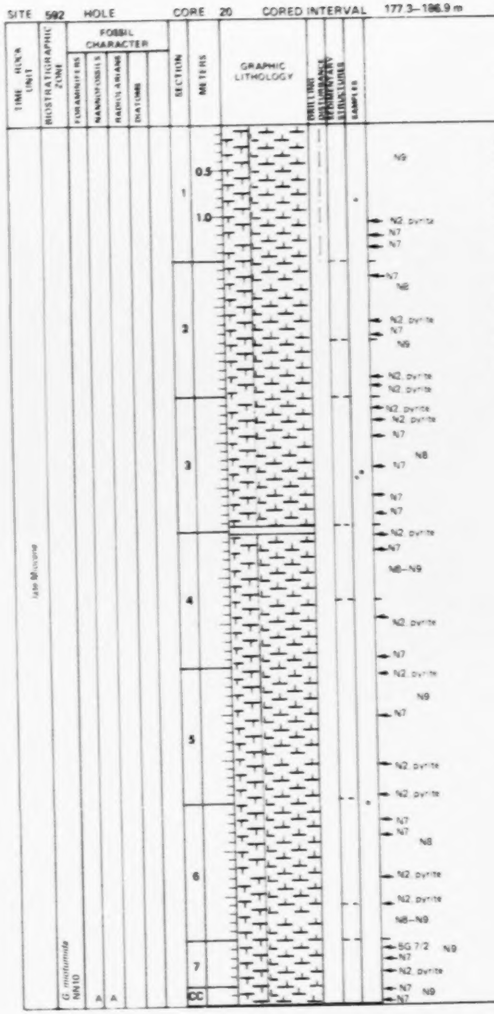
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (>5%) NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), massive with light gray (N7) pyritized blebs and streaks. Rare pale green (5G 7/2) laminae.

SMEAR SLIDE SUMMARY

	2, 77	5, 56	5, 85
	D	D	M
Texture			
Silt	C	C	C
Clay	D	D	D
Composition			
Volcanic glass	–	–	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 592 HOLE CORE 20 CORED INTERVAL 177.3–186.9 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN10
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
N2 pyrite
N7
N7
N7
N8
N2 pyrite
N7
N9
N2 pyrite
N2 pyrite
N2 pyrite
N2 pyrite
N7
N8
N7
N7
N7
N2 pyrite
N7
N8–N9
N2 pyrite
N7
N2 pyrite
N9
N7
N2 pyrite
N2 pyrite
N7
N7
N8
N2 pyrite
N2 pyrite
N8–N9
5G 7/2 N9
N7
N2 pyrite
N7 N9
N7

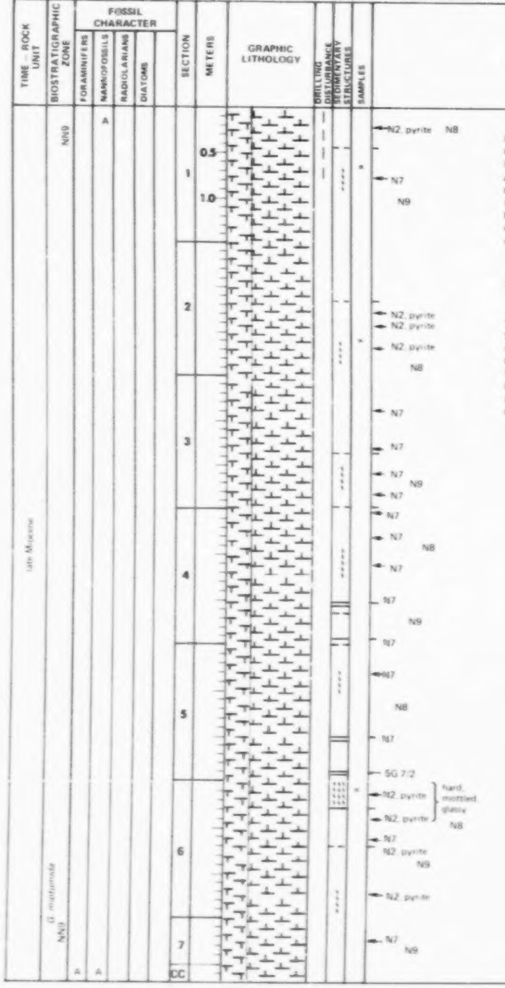
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE TO FORAMINIFER-BEARING (5–20%) NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), massive with occasional light gray (N7) pyritized streaks and blebs. Irregular alternation of N8 and N9 color units with N8 enriched (5–20%) in foraminifers, all boundaries gradational. Pale green lamina in Section 7.

SMEAR SLIDE SUMMARY

	1, 82	3, 81
	D	D
Texture		
Silt	R	C
Clay	D	D
Composition		
Volcanic glass	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 21 CORED INTERVAL 186.9–196.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN9
G. miotumida
NN9
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N2, pyrite
N8
N7
N9
N2, pyrite
N2, pyrite
N2, pyrite
N8
N7
N7
N7
N9
N7
N7
N7
N8
N7
N7
N9
N7
N7
N8
N7
5G 7/2
N2, pyrite
N2, pyrite
hard, mottled, glassy
N8
N7
N2, pyrite
N9
N2, pyrite
N7
N9

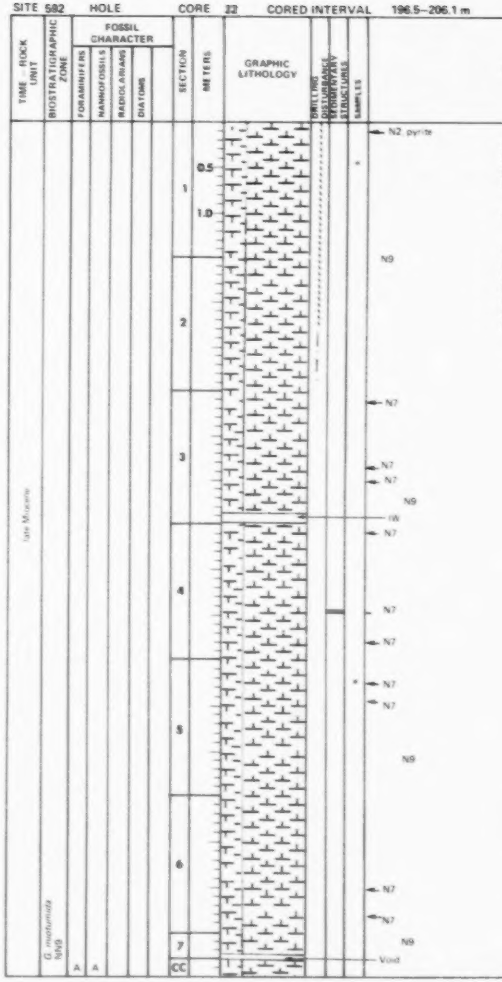
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (5–10%) NANNOFOSSIL OOZE TO (RARELY) FORAMINIFER (25–30%) NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8) in alternating units, the former with 10% foraminifers and the latter with 10–30% foraminifers, pyritized light gray (N7) blebs, streaks, and laminae scattered throughout. Pale green (5G 7/2) lamina in Section 5 with underlying 40 cm indurated, burrow mottled and containing scattered volcanic glass and py···

SMEAR SLIDE SUMMARY

	1, 68	2, 112	6, 15
	D	D	M
Texture:			
Silt	C	A	C
Clay	D	A	D
Composition:			
Volcanic glass	—	—	R
Pyrite	—	T	—
Foraminifers	C	A	C
Calc. nannofossils	D	A	D

SITE 582 HOLE CORE 22 CORED INTERVAL 196.5–206.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN9
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N2, pyrite
N9
N7
N7
N7
N9
IW
N7
N7
N7
N7
N7
N9
N7
N7
N9
Void

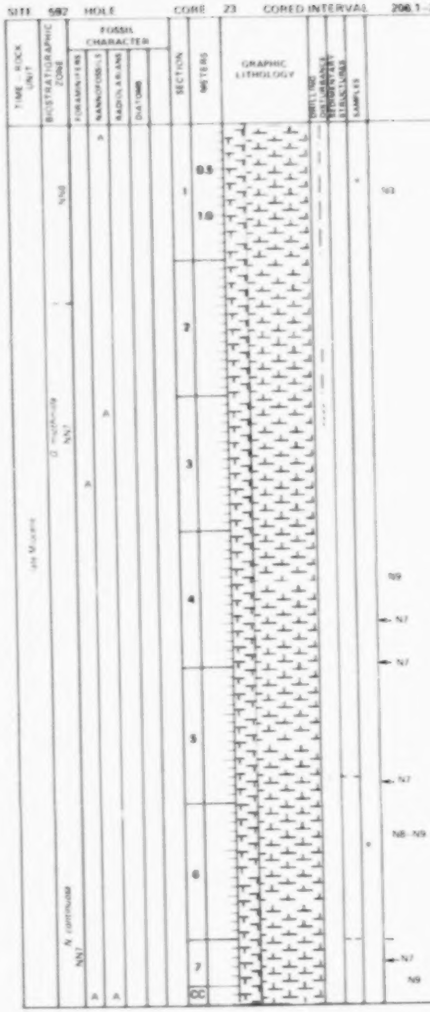
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (5–10%) NANNOFOSSIL OOZE, soft, predominantly white (N9) with rare very light gray (N8) shades, massive with rare light gray (N7) pyritized blebs. Featureless core compared to those above.

SMEAR SLIDE SUMMARY

	1, 47	5, 23
	D	D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 23 CORED INTERVAL 206.1–215.7 m


TIME–ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN8
G. nepenthes
NN7
N. continuosa
NN7
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
N9
N7
N7
N7
N8–N9
N7
N9

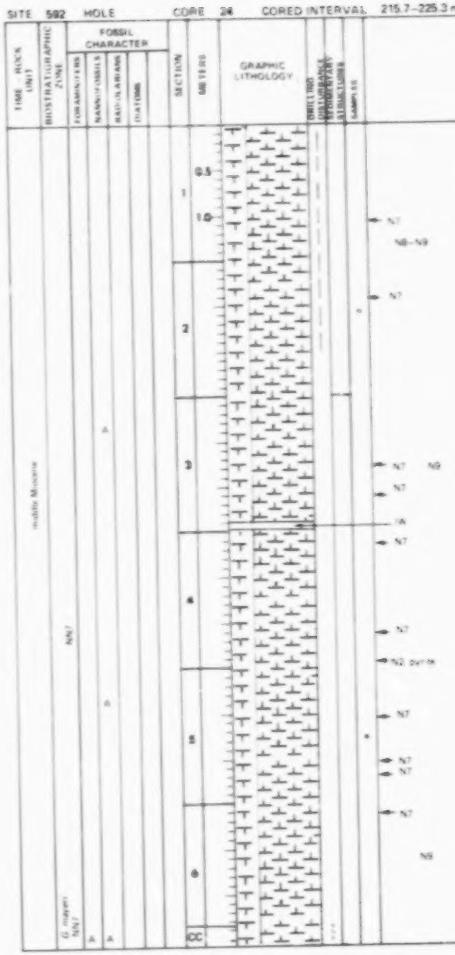
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (5–10%) NANNOFOSSIL OOZE, soft but firm, predominantly white (N9) with shades of N8 in some portions, massive with very rare light gray (N7) pyritized blebs. Featureless core overall.

SMEAR SLIDE SUMMARY

	1, 64	6, 45
	D	D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 24 CORED INTERVAL 215.7–225.3 m


TIME–ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN7
G. mayeri
NN7
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
N7
N8–N9
N7
N7
N9
N7
IW
N7
N7
N2 pyrite
N7
N7
N7
N7
N9

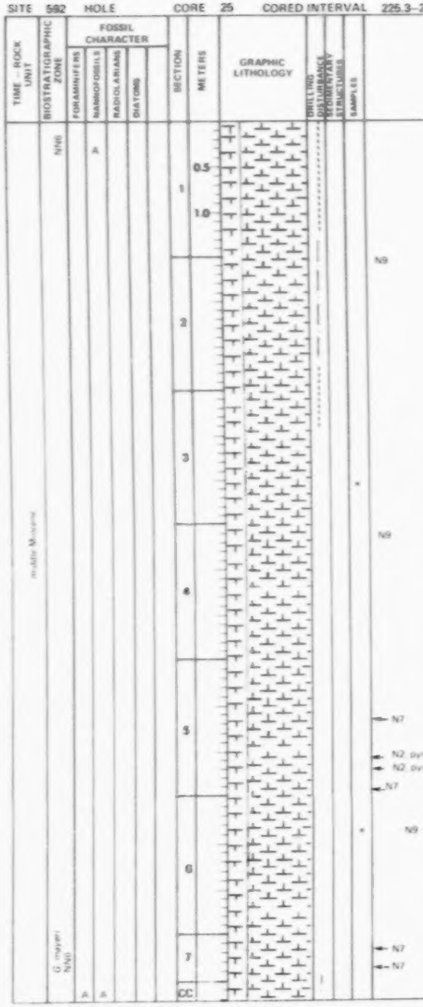
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (~5%) NANNOFOSSIL OOZE, soft but firm, predominantly white (N9) with shades of very light gray (N8) in Sections 1 and 2, massive with rare light gray (N7) pyritized blebs and streaks.

SMEAR SLIDE SUMMARY

	2, 72	5, 75
	D	D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	—
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 25 CORED INTERVAL 225.3–234.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
G. mayeri
NN6
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N9
N9
N7
N2 pyrite
N2 pyrite
N7
N9
N7
N7

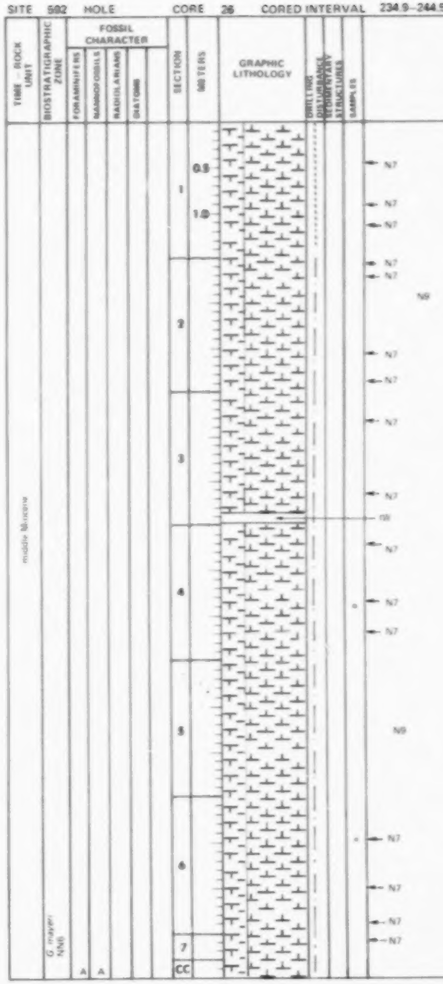
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING (5–10%) NANNOFOSSIL OOZE, soft, white (N9), massive with very rare light gray (N7) pyritized blebs.

SMEAR SLIDE SUMMARY

	3, 107	6, 40
	D	D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 26 CORED INTERVAL 234.9–244.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri
NN6
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N7
N7
N7
N7
N9
N7
N7
N7
N7
N8
N7
N7
N7
N9
N7
N7
N7
N7

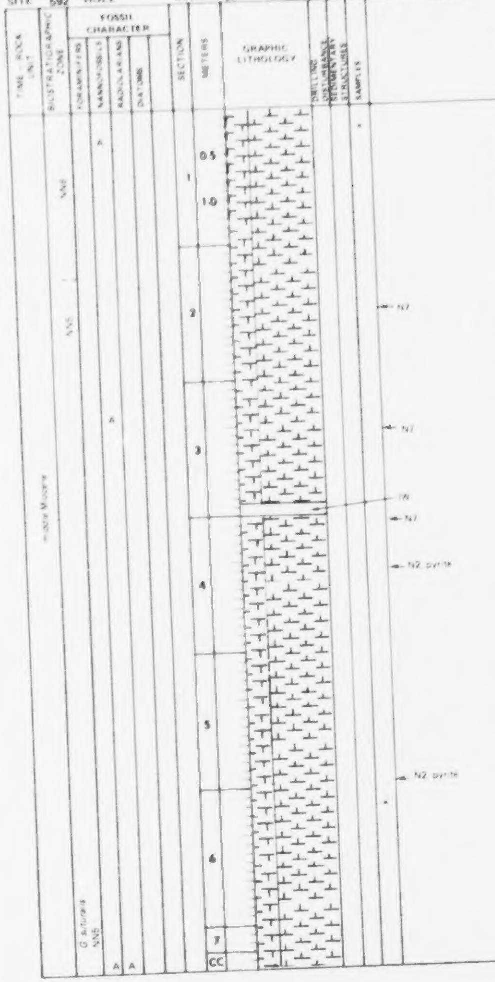
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING (~5%) NANNOFOSSIL OOZE, soft, white, massive with rare light gray (N7) pyritized blebs which are streaked out to varying degree by coring disturbance.

SMEAR SLIDE SUMMARY

	4, 88	6, 95
	D	M
Texture:		
Silt	R	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 592 HOLE CORE 28 CORED INTERVAL 254.1–263.7 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
NN5
G. fohsi
NN5
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N7
IW
N7
N2 pyrite
N2 pyrite

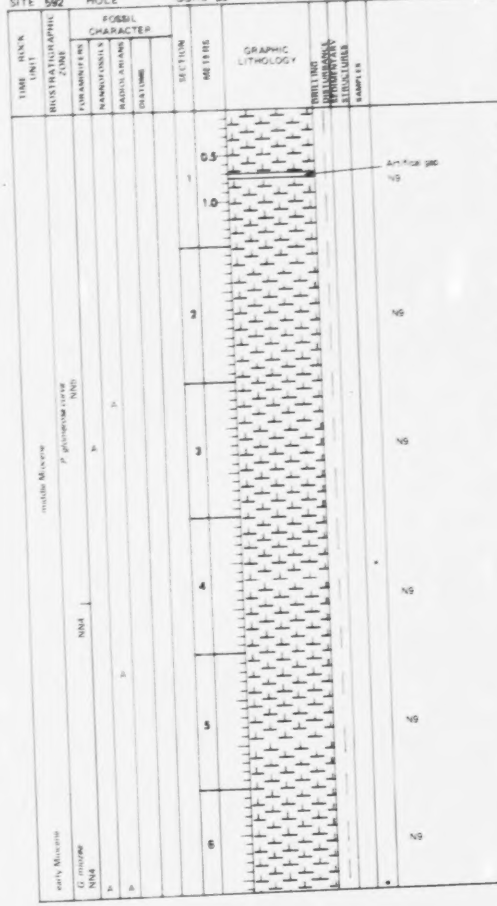
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING (5–10%) NANNOFOSSIL OOZE, soft, with occasional firmer biscuits, white (N9) to bluish white (5B 9/1); entirely massive except for very rare light gray (N7) and grayish black (N2) pyritized burrows and blebs more intensely white than above cores and uniformity makes evaluation of possible coring disturbance difficult.

SMEAR SLIDE SUMMARY

	1, 26 D	6, 20 D
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Volcanic glass	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

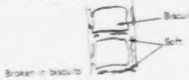
SITE 592 HOLE CORE 29 CORED INTERVAL 263.7–273.3 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva
NN5
NN4
early Miocene
G. insueta
NN4
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
Artificial gap
N9
N9
N9
N9
N9
N9

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft to firm, white (N9), homogeneous.

Drilling disturbance:

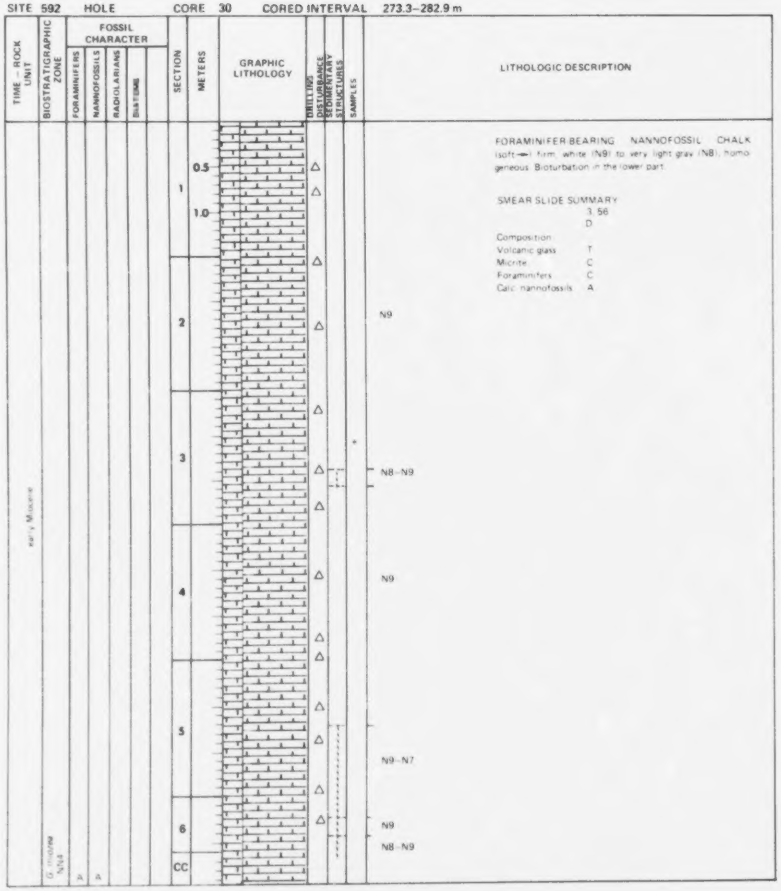

Biscuit
Soft
Broken in biscuits

SMEAR SLIDE SUMMARY

	4, 67 D	6, 115*
Composition:		
Quartz	–	T
Feldspar	–	T
Heavy minerals	–	T
Clay	–	A
Volcanic glass	T	C
Pyrite	–	T
Foraminifers	R	–
Calc. nannofossils	D	–
Radiolarians	T	–

*Insoluble residue

SITE 592 HOLE CORE 30 CORED INTERVAL 273.3–282.9 m

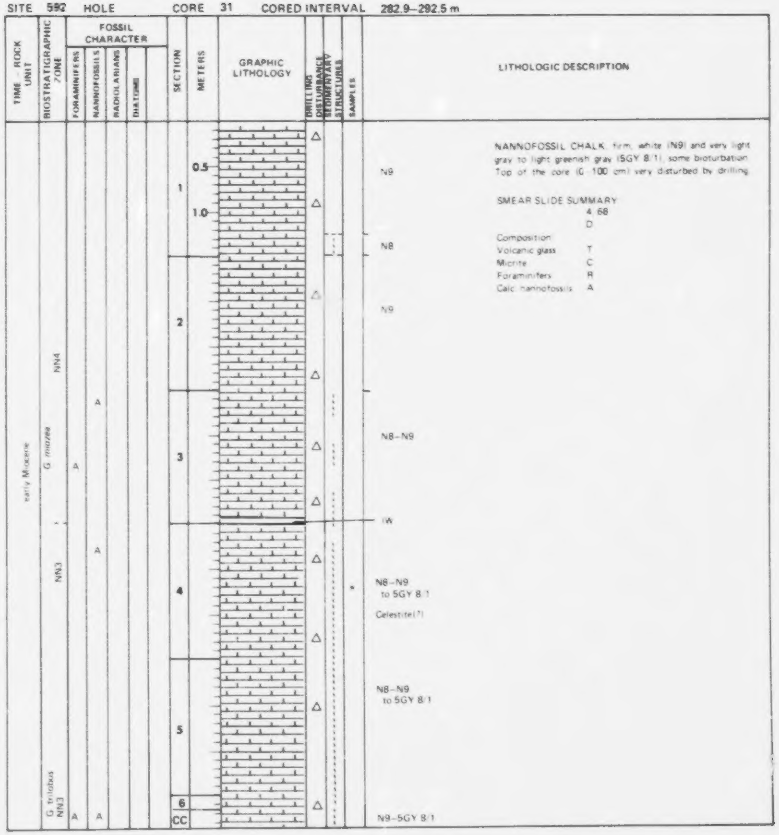

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
G. miozea
NN4
A
A
1
2
3
4
5
6
CC
0.5
1.0
N9
N8–N9
N9
N9–N7
N9
N8–N9

FORAMINIFER BEARING NANNOFOSSIL CHALK (soft→) firm, white (N9) to very light gray (N8), homogeneous. Bioturbation in the lower part.

SMEAR SLIDE SUMMARY

	3, 56
	D
Composition	
Volcanic glass	T
Micrite	C
Foraminifers	C
Calc. nannofossils	A

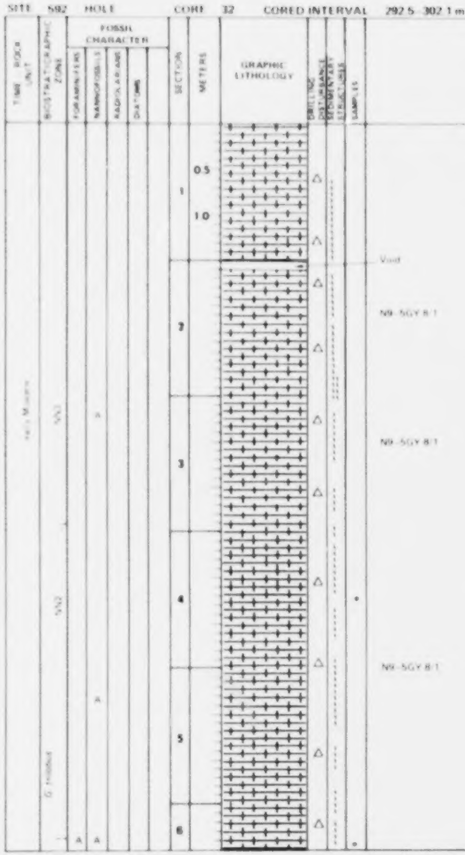
SITE 592 HOLE CORE 31 CORED INTERVAL 282.9–292.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
G. miozea
NN4
NN3
G. trilobus
NN3
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N9
N8
N9
N8–N9
IW
N8–N9
to 5GY 8/1
Celestite(?)
N8–N9
to 5GY 8/1
N9–5GY 8/1

NANNOFOSSIL CHALK, firm, white (N9) and very light gray to light greenish gray (5GY 8/1), some bioturbation. Top of the core (0–100 cm) very disturbed by drilling.

SMEAR SLIDE SUMMARY

	4, 68
	D
Composition	
Volcanic glass	T
Micrite	C
Foraminifers	R
Calc. nannofossils	A


SITE 592 HOLE CORE 32 CORED INTERVAL 292.5–302.1 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN2
NN2
A
A
A
A
1
2
3
4
5
6
0.5
1.0
Void
N9–5GY 8/1
N9–5GY 8/1
N9–5GY 8/1

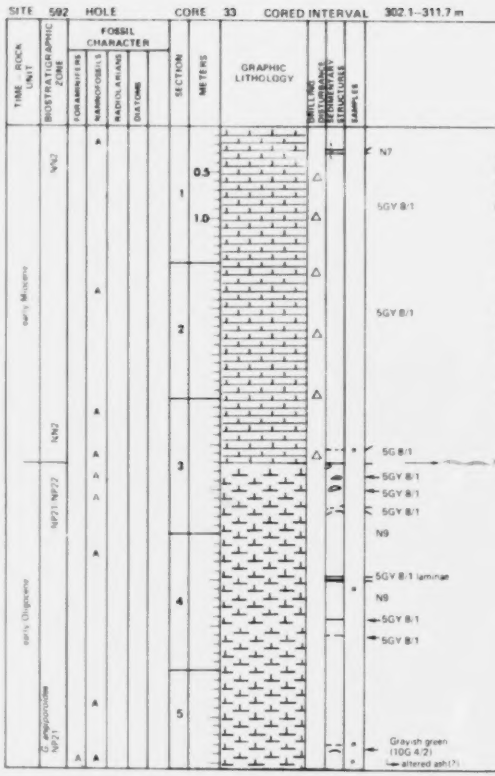
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, white (N9) to very light greenish gray (5GY 8/1), moderately bioturbated.

SMEAR SLIDE SUMMARY

	4, 71	6, 50[a]
	D	M
Composition		
Feldspar		T
Heavy minerals		T
Clay	–	A
Volcanic glass	T	T
Pyrite	–	T
Micrite	C	
Foraminifers	R	
Calc. nannofossils	A	–
Undefined	–	C

[a] Insoluble residue


SITE 592 HOLE CORE 33 CORED INTERVAL 302.1–311.7 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
early Oligocene
NN2
NN2
NP21 NP22
G. angiporoides NP21
A
A
A
A
A
A
A
A
A
1
2
3
4
5
0.5
1.0
N7
5GY 8/1
5GY 8/1
5G 8/1
?
5GY 8/1
5GY 8/1
5GY 8/1
N9
5GY 8/1 laminae
N9
5GY 8/1
5GY 8/1
Grayish green (10G 4/2)
altered ash(?)

LITHOLOGIC DESCRIPTION

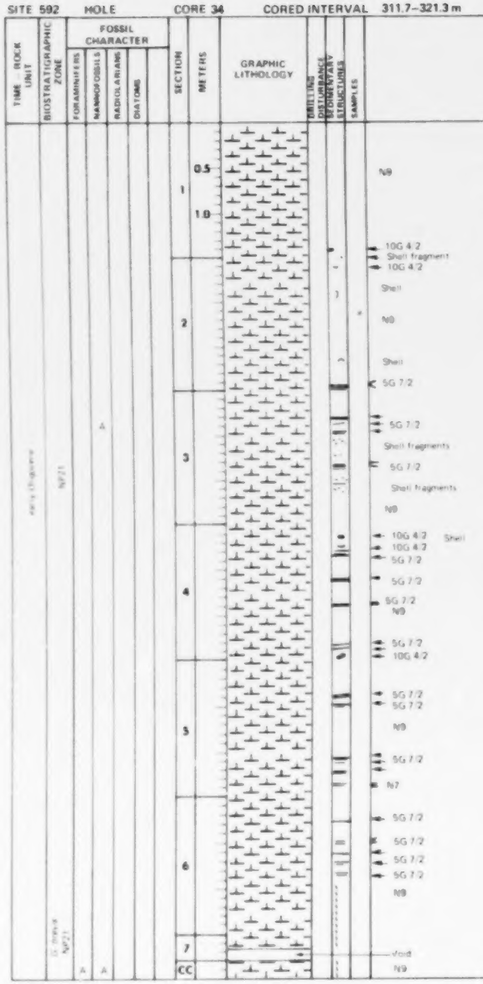
NANNOFOSSIL CHALK, firm, light greenish gray (5GY 8/1 to 5G 8/1), some bioturbation in the upper part. Sharp boundary near 70 cm in Section 3: below soft, white (N9), sometimes light greenish gray (5GY 8/1) laminae
└NANNOFOSSIL OOZE

SMEAR SLIDE SUMMARY

	3, 60	4, 60	5, 77	CC[a]
	D	D	M	M
Composition				
Quartz	–	–	–	T
Feldspar	T	–	–	T
Heavy minerals	–	–	T	–
Volcanic glass	T	–	D	T
Pyrite	T	–	–	–
Zeolites	–	–	–	D
Micrite	C	–	–	–
Foraminifers	R	R	R	–
Calc. nannofossils	A	D	A	–

[a] Insoluble residue

SITE 592 HOLE CORE 34 CORED INTERVAL 311.7–321.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP21
G. brevis NP21
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
10G 4/2
Shell fragment
10G 4/2
Shell
N9
Shell
5G 7/2
5G 7/2
Shell fragments
5G 7/2
Shell fragments
N9
10G 4/2
Shell
10G 4/2
5G 7/2
5G 7/2
5G 7/2
N9
5G 7/2
10G 4/2
5G 7/2
5G 7/2
N9
5G 7/2
N7
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N9
Void
N9

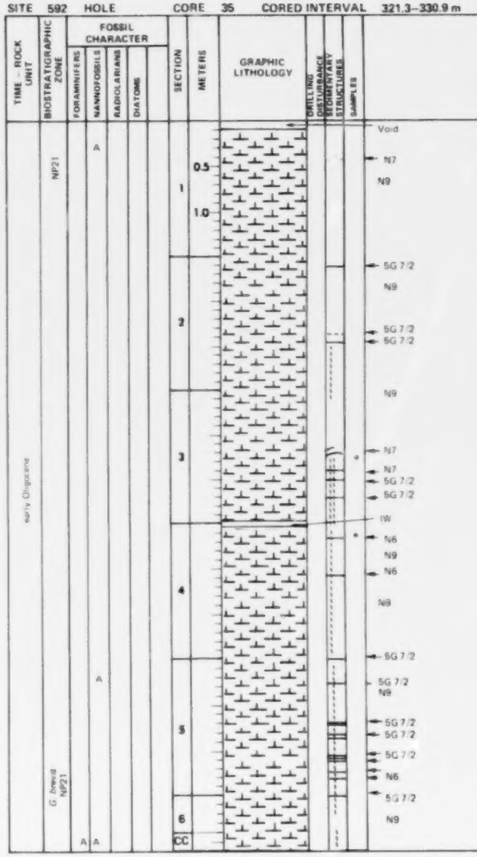
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9), thin pale green (5G 7/2) laminae and grayish green (10G 7/2) pockets ←volcanic glass (smear slide); Sections 1–4 shell fragments (oysters), 1–4 cm size; bioturbation in Sections 6 and 7 (beautiful *Zoophycos*, *Planolites*).

SMEAR SLIDE SUMMARY

	2, 66	4, 141
	D	M
Composition:		
Volcanic glass	T	A
Pyrite	–	R
Foraminifers	R	T
Calc. nannofossils	D	A

SITE 592 HOLE CORE 35 CORED INTERVAL 321.3–330.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP21
G. brevis NP21
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
Void
N7
N9
5G 7/2
N9
5G 7/2
5G 7/2
N9
N7
N7
5G 7/2
5G 7/2
IW
N6
N9
N6
N9
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2
N6
5G 7/2
N9

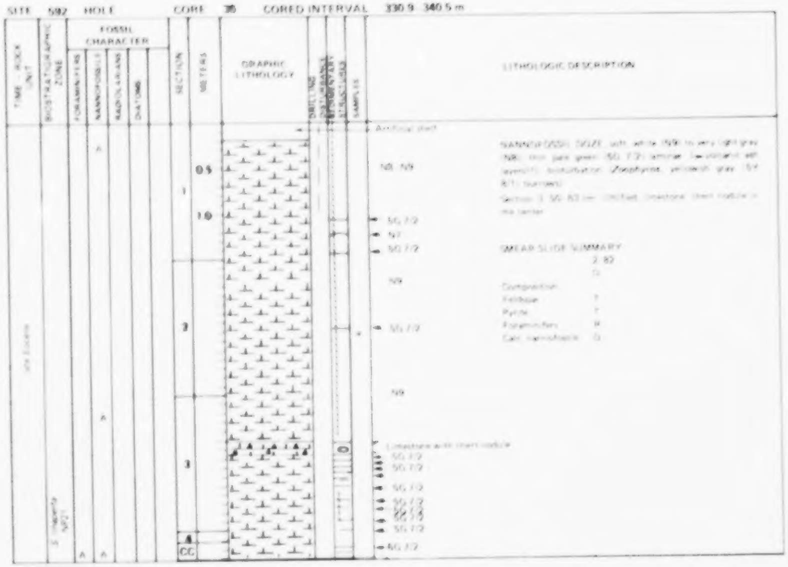
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9), upper part homogeneous (Section 1), thin pale green (5G 7/2) laminae, (←volcanic ash layers?), moderate bioturbation (beautiful *Zoophycos*).

SMEAR SLIDE SUMMARY

	3, 78	4, 14
	D	M
Composition:		
Feldspar	T	–
Heavy minerals	–	T
Volcanic glass	T	–
Pyrite	–	C
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	T	–

SITE 592 HOLE CORE 36 CORED INTERVAL 330.9–340.5 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
NP21
A
A
A
A
0.5
1.0
1
2
3
4
CC
Artificial chert
N8, N9
5G 7/2
N7
5G 7/2
N9
5G 7/2
N9
Limestone with chert nodule
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2

LITHOLOGIC DESCRIPTION

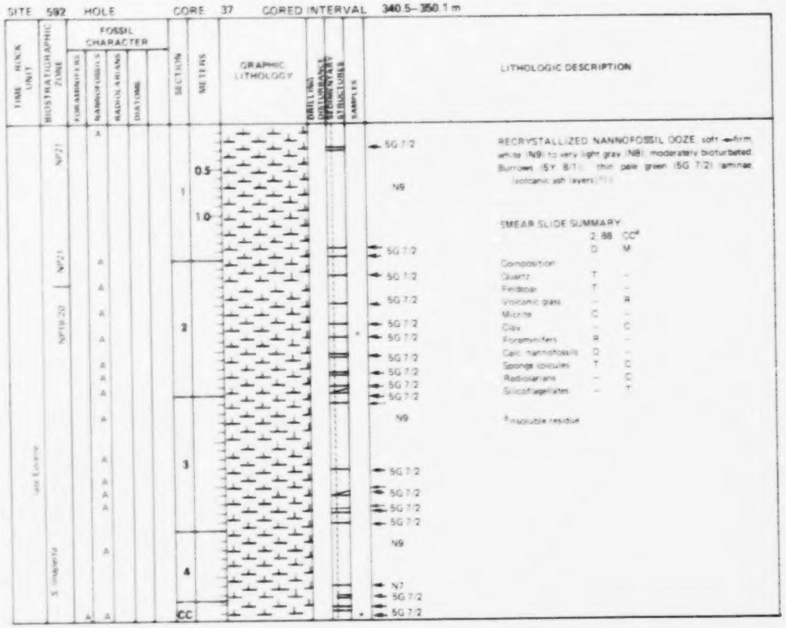
NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8); thin pale green (5G 7/2) laminae (= volcanic ash layers(?)); bioturbation; *Zoophycos*, yellowish gray (5Y 8/1) burrows.

Section 3, 50–63 cm: Lithified limestone; chert nodule in the center.

SMEAR SLIDE SUMMARY

	2, 82
	D
Composition:	
Feldspar	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 592 HOLE CORE 37 CORED INTERVAL 340.5–350.1 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
NP21
NP21
NP19-20
A
A
A
A
A
A
A
A
A
A
A
A
A
A
A
A
0.5
1.0
1
2
3
4
CC
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N9
N7
5G 7/2
5G 7/2

LITHOLOGIC DESCRIPTION

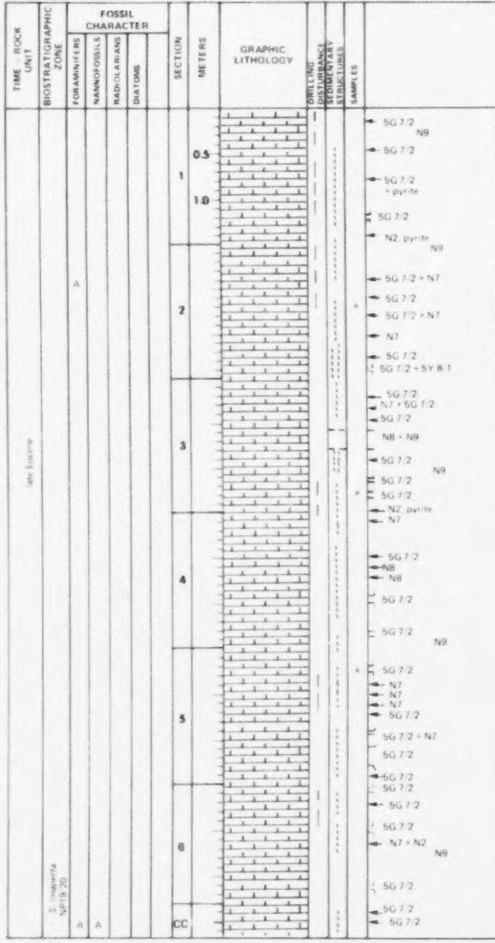
RECRYSTALLIZED NANNOFOSSIL OOZE, soft → firm, white (N9) to very light gray (N8), moderately bioturbated. Burrows (5Y 8/1); thin pale green (5G 7/2) laminae (volcanic ash layers(?)).

SMEAR SLIDE SUMMARY

	2, 88	CC[a]
	D	M
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	–	R
Micrite	C	–
Clay	–	C
Foraminifers	R	–
Calc. nannofossils	D	–
Sponge spicules	T	C
Radiolarians	–	C
Silicoflagellates	–	T

[a] Insoluble residue

SITE 592 HOLE CORE 38 CORED INTERVAL 350.1–359.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
S. linaperta NP19/20
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
*
5G 7/2
N9
5G 7/2
5G 7/2 + pyrite
5G 7/2
N2, pyrite
N9
5G 7/2 + N7
5G 7/2
5G 7/2 + N7
N7
5G 7/2
5G 7/2 + 5Y 8/1
5G 7/2
N7 + 5G 7/2
5G 7/2
N8 + N9
5G 7/2
N9
5G 7/2
5G 7/2
N2, pyrite
N7
5G 7/2
N8
N8
5G 7/2
5G 7/2
N9
5G 7/2
N7
N7
N7
5G 7/2
5G 7/2 + N7
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N7 + N2
N9
5G 7/2
5G 7/2
5G 7/2

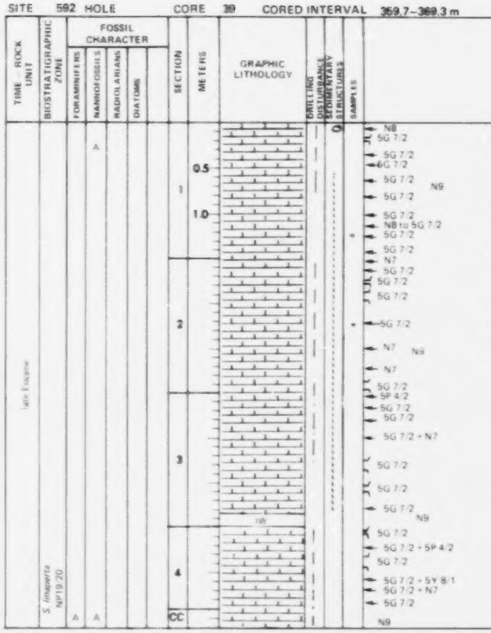
LITHOLOGIC DESCRIPTION

NANNOFOSSIL (OOZE TO) CHALK, soft to firm, white (N9) to rarely very light gray (N8), with many levels of pale green (5G 7/2) color laminations superimposed, as well as less common light gray (N7) and grayish black (N2) pyritized laminae, wisps, halos and blebs. Bioturbation slight to moderate with some *Zoophycos* and *Chondrites*.

SMEAR SLIDE SUMMARY

	2, 73	5, 32	3, 133
	D	M	D
Texture:			
Silt	R	R	R
Clay	D	D	D
Composition:			
Quartz	–	T	–
Volcanic glass	T	R	T
Carbonate unspec	C	C	C
Foraminifers	R	R	R
Calc. nannofossils	D	D	D

SITE 592 HOLE CORE 39 CORED INTERVAL 359.7–369.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
S. linaperta NP19/20
A
A
A
0.5
1.0
1
2
3
4
CC
IW
N8
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2
N8 to 5G 7/2
5G 7/2
5G 7/2
N7
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N7
N9
N7
5G 7/2
5P 4/2
5G 7/2
5G 7/2
5G 7/2 + N7
5G 7/2
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2 + 5P 4/2
5G 7/2
5G 7/2 + 5Y 8/1
5G 7/2 + N7
5G 7/2
N9

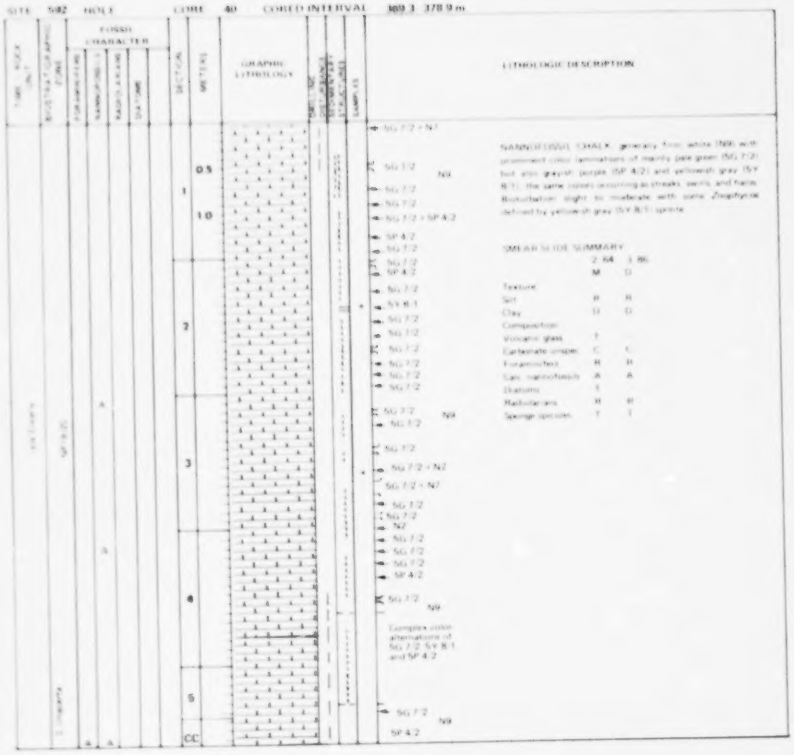
LITHOLOGIC DESCRIPTION

NANNOFOSSIL (OOZE TO) CHALK, firm (softer intervals possibly due to coring), white (N9) with very common superimposed pale gray (5G 7/2) color laminae and less common light gray (N7) and grayish purple (5P 4/2) wisps, laminae and blebs. Slight to moderate bioturbation with *Zoophycos* and *Planolites*-like burrows evident in yellowish gray (5Y 8/1) tones.

SMEAR SLIDE SUMMARY

	1, 126	2, 84
	D	M
Texture:		
Silt	R	R
Clay	D	D
Composition:		
Volcanic glass	T	T
Carbonate unspec	C	C
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 592 HOLE CORE 40 CORED INTERVAL 369.3–378.9 m


TIME-ROCK UNIT
late Eocene
BIOSTRATIGRAPHIC ZONE
NP19-20
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
A
A
A A
SECTION
METERS
0.5
1.0
1
2
3
4
5
CC
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
*
*
5G 7/2 + N7
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2 + 5P 4/2
5P 4/2
5G 7/2
5G 7/2
5P 4/2
5G 7/2
5Y 8/1
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2 + N7
5G 7/2 + N7
5G 7/2
5G 7/2
N7
5G 7/2
5G 7/2
5G 7/2
5P 4/2
5G 7/2
N9
Complex color alternations of 5G 7/2, 5Y 8/1 and 5P 4/2
5G 7/2
N9
5P 4/2

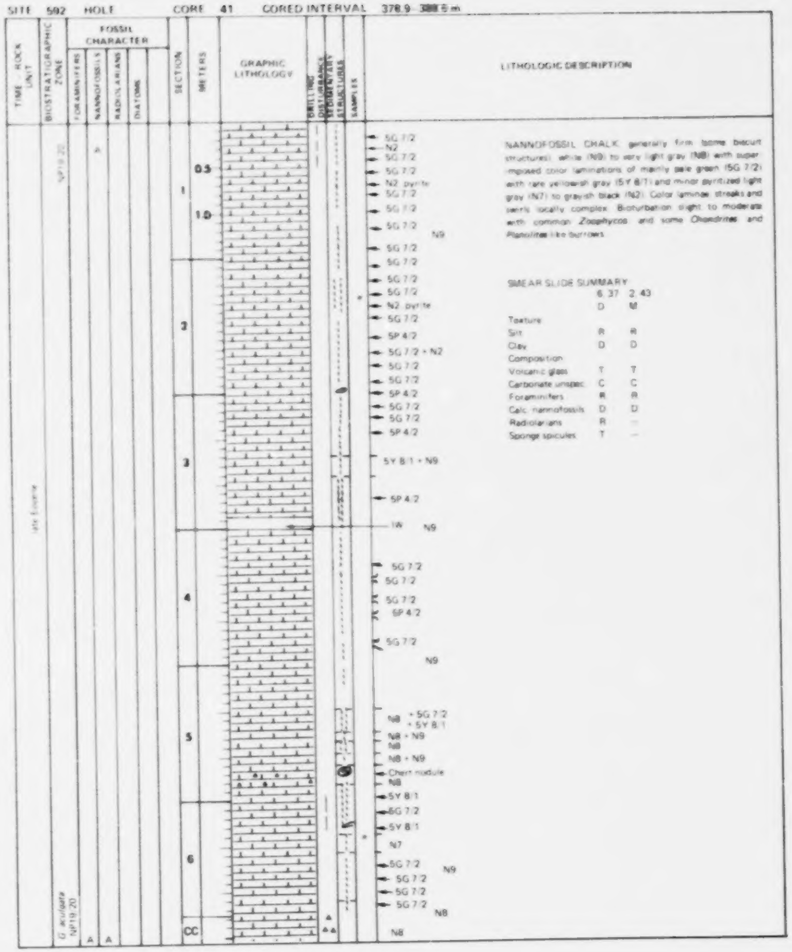
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, generally firm, white (N9) with prominent color laminations of mainly pale green (5G 7/2) but also grayish purple (5P 4/2) and yellowish gray (5Y 8/1), the same colors occurring as streaks, swirls and haze. Bioturbation slight to moderate with some *Zoophycos* defined by yellowish gray (5Y 8/1) sprite.

SMEAR SLIDE SUMMARY

	2, 64	3, 86
	M	D
Texture		
Silt	R	R
Clay	D	D
Composition		
Volcanic glass	T	
Carbonate unspec	C	C
Foraminifers	R	R
Calc. nannofossils	A	A
Diatoms	T	
Radiolarians	R	R
Sponge spicules	T	T

SITE 592 HOLE CORE 41 CORED INTERVAL 378.9–388.5 m


TIME-ROCK UNIT
late Eocene
BIOSTRATIGRAPHIC ZONE
NP19-20
G. aculeata
NP19-20
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
A
A A
SECTION
METERS
0.5
1.0
1
2
3
4
5
6
CC
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
*
*
*
5G 7/2
N2
5G 7/2
5G 7/2
N2 pyrite
5G 7/2
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2
5G 7/2
N2 pyrite
5G 7/2
5P 4/2
5G 7/2 + N2
5G 7/2
5G 7/2
5P 4/2
5G 7/2
5G 7/2
5P 4/2
5Y 8/1 + N9
5P 4/2
IW
N9
5G 7/2
5G 7/2
5G 7/2
5P 4/2
5G 7/2
N9
N8 + 5G 7/2 + 5Y 8/1
N8 + N9
N8
N8 + N9
Chert nodule
N8
5Y 8/1
5G 7/2
5Y 8/1
N7
5G 7/2
N9
5G 7/2
5G 7/2
5G 7/2
N8
N8

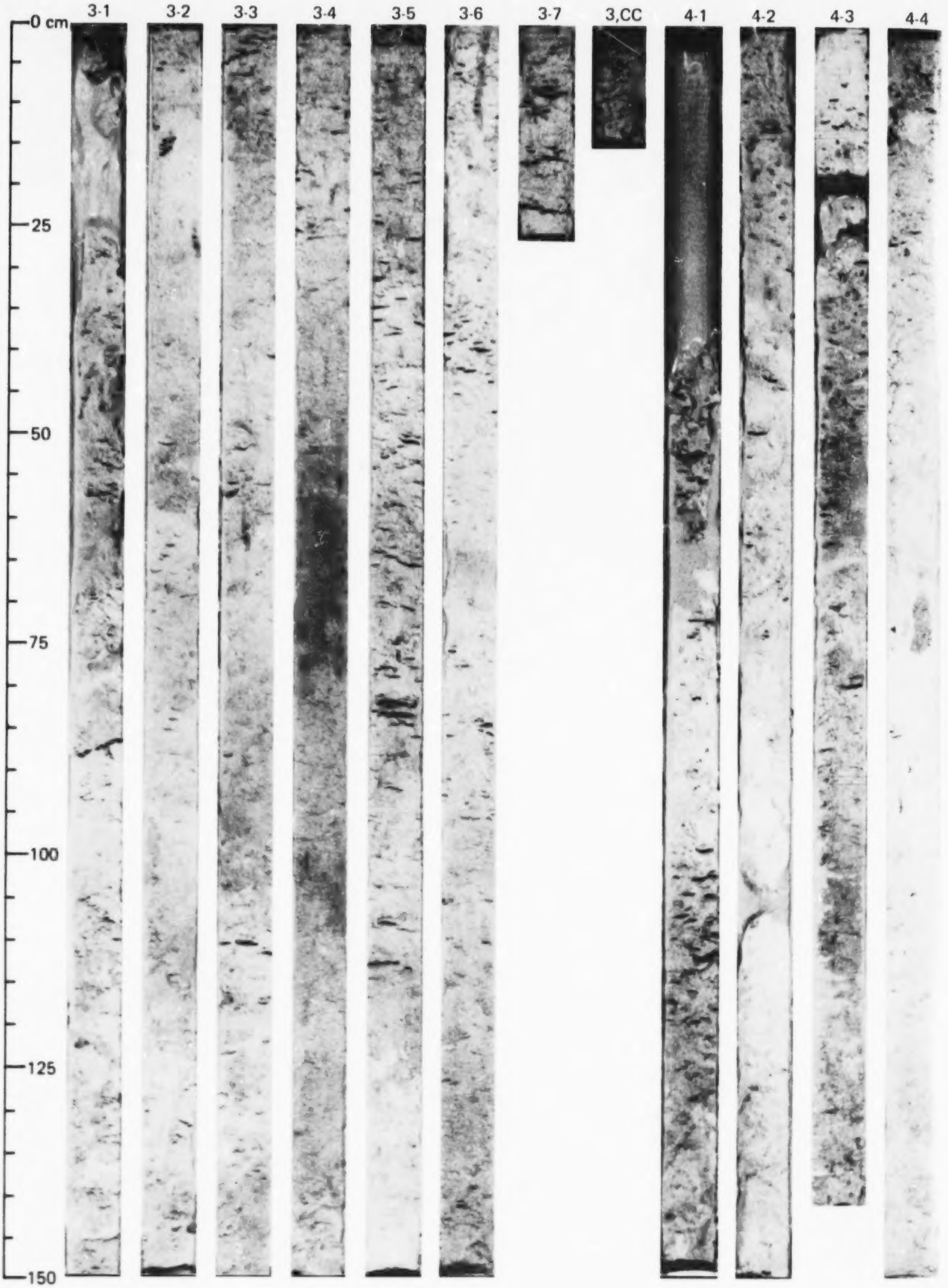
LITHOLOGIC DESCRIPTION

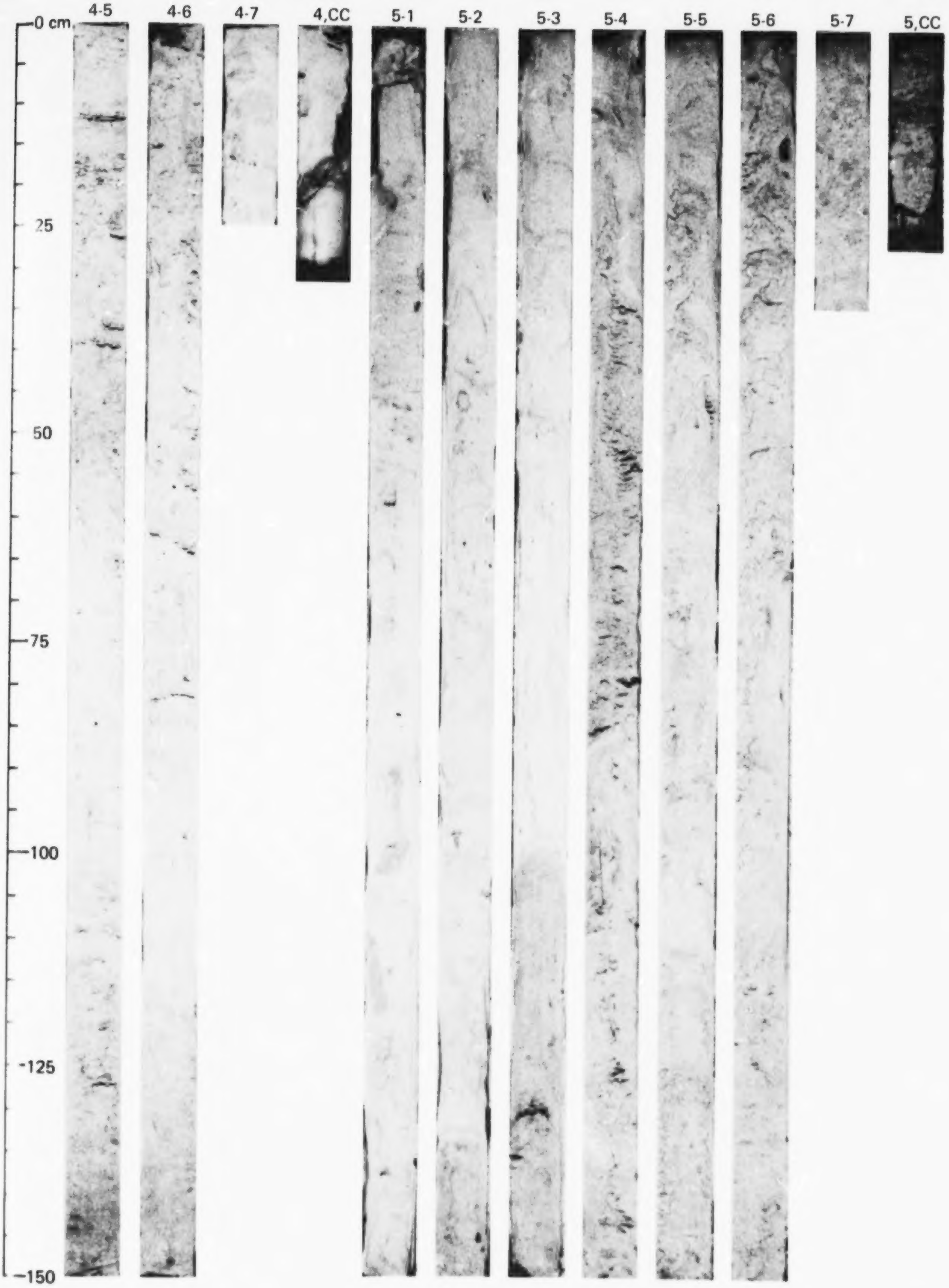
NANNOFOSSIL CHALK, generally firm (some biscuit structures), white (N9) to very light gray (N8) with superimposed color laminations of mainly pale green (5G 7/2) with rare yellowish gray (5Y 8/1) and minor pyritized light gray (N7) to grayish black (N2). Color laminae, streaks and swirls locally complex. Bioturbation slight to moderate with common *Zoophycos* and some *Chondrites* and *Planolites* like burrows.

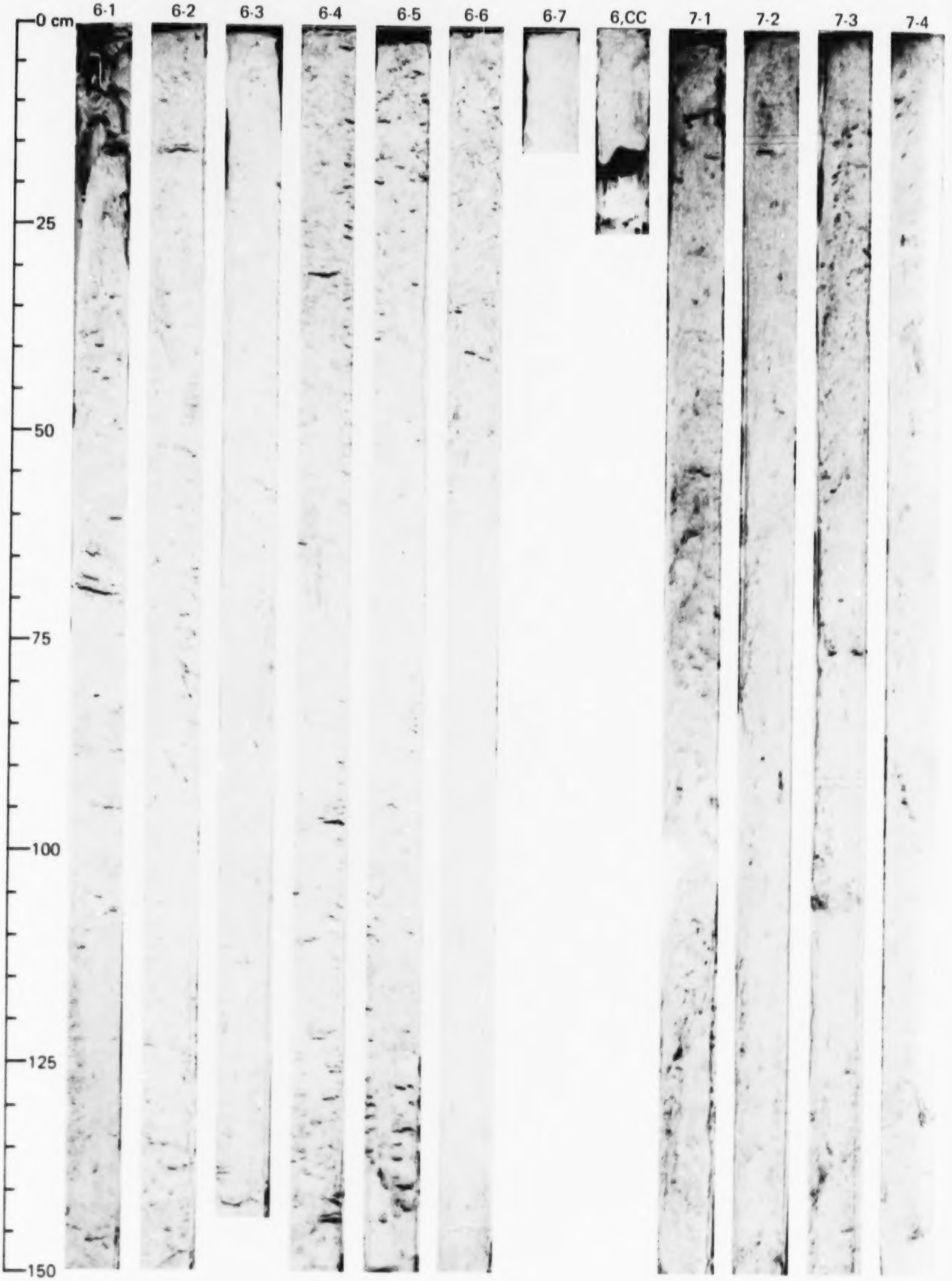
SMEAR SLIDE SUMMARY

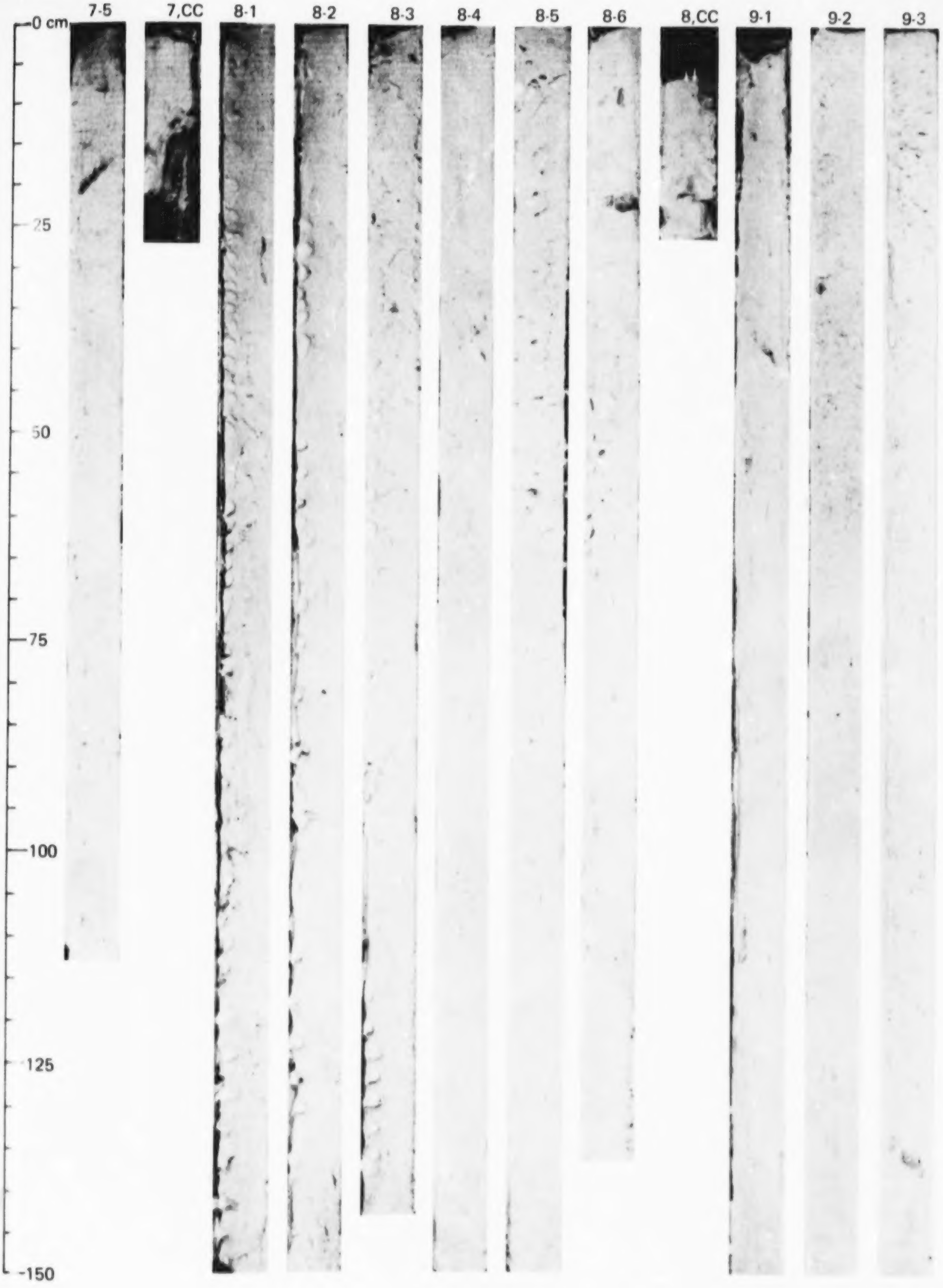
	6, 37	2, 43
	D	M
Texture		
Silt	R	R
Clay	D	D
Composition		
Volcanic glass	T	T
Carbonate unspec	C	C
Foraminifers	R	R
Calc. nannofossils	D	D
Radiolarians	R	—
Sponge spicules	T	—

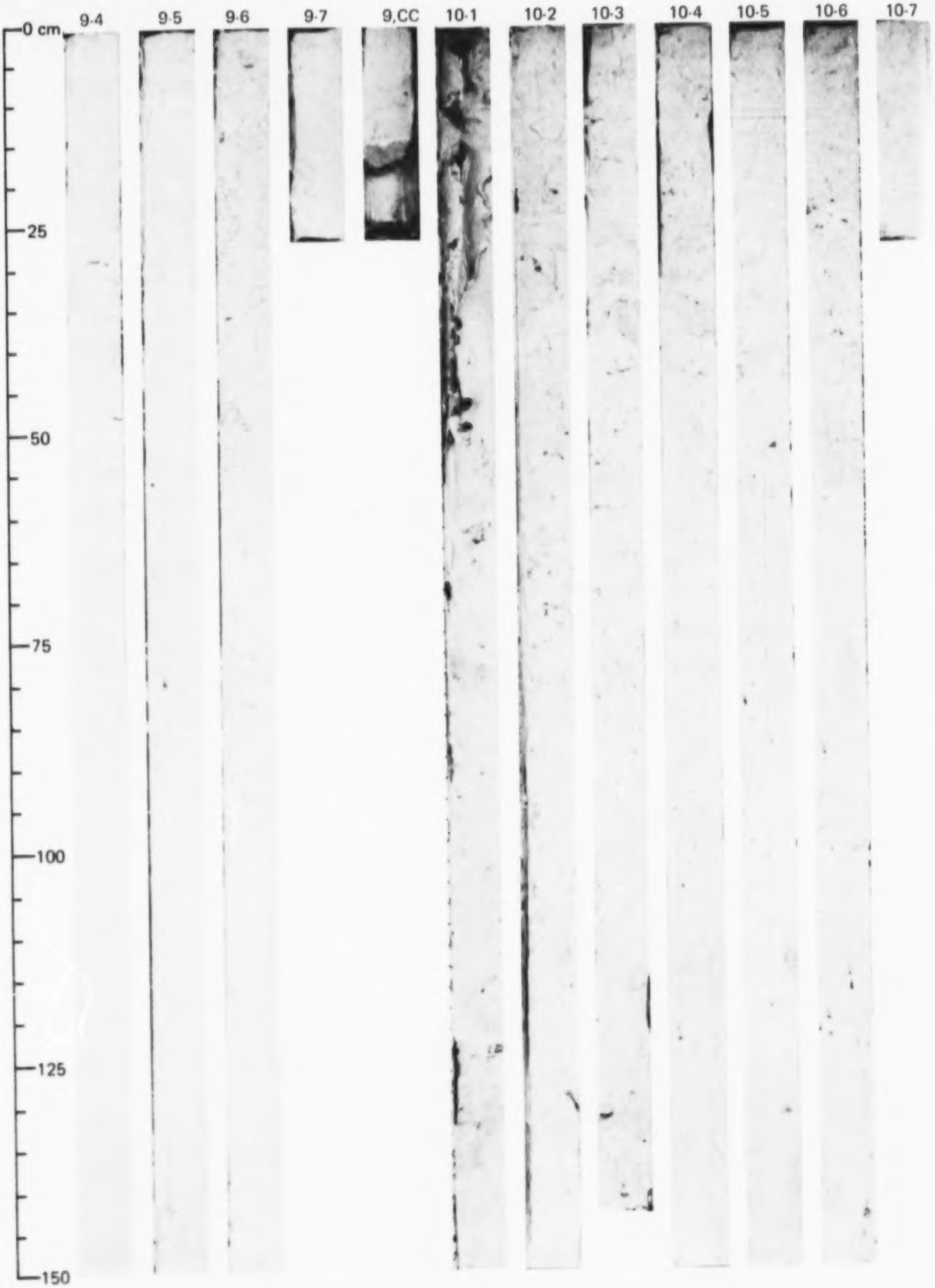
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2-7
2,CC

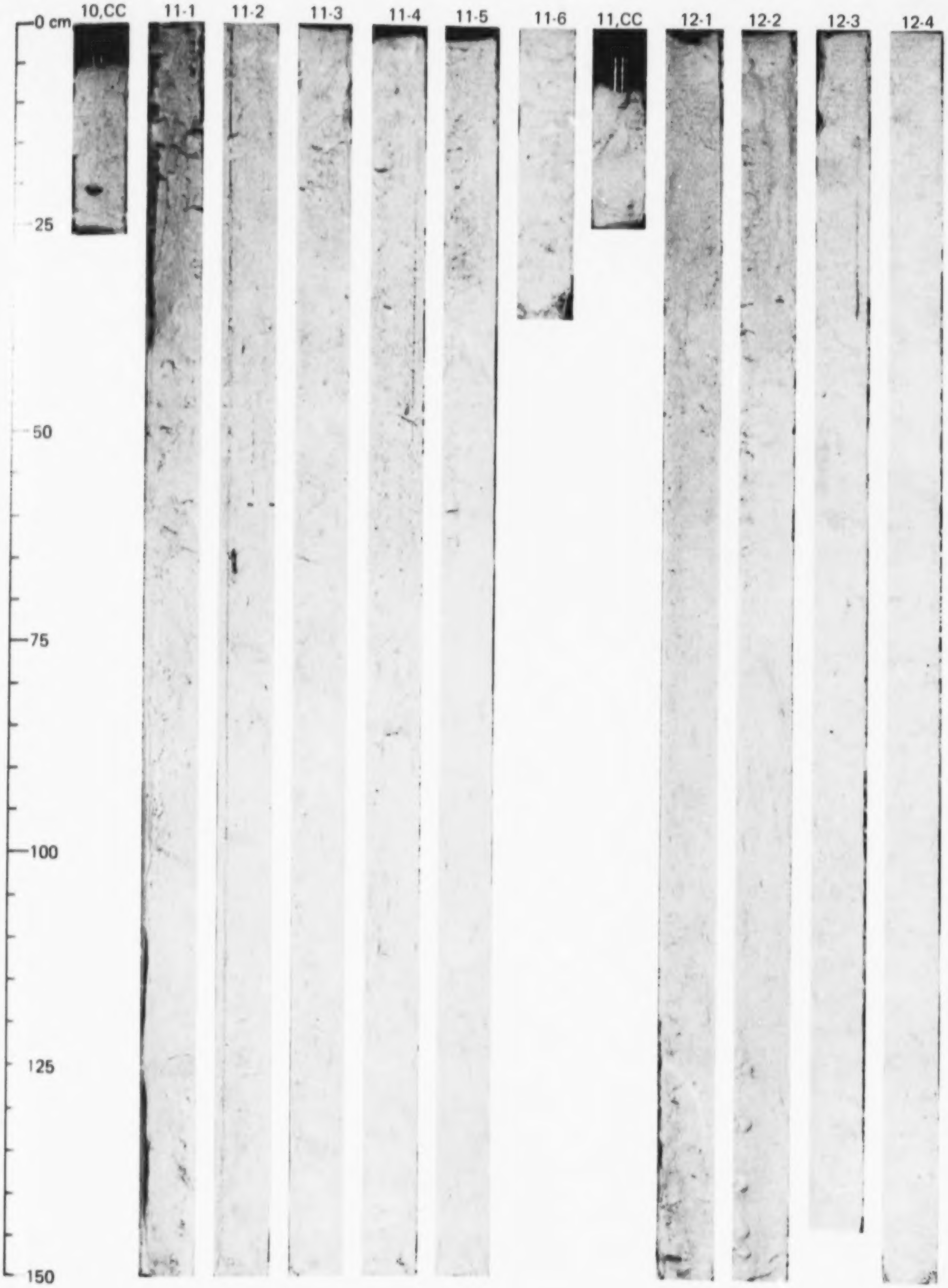

0 cm
25
50
75
100
125
150
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3,CC
4-1
4-2
4-3
4-4

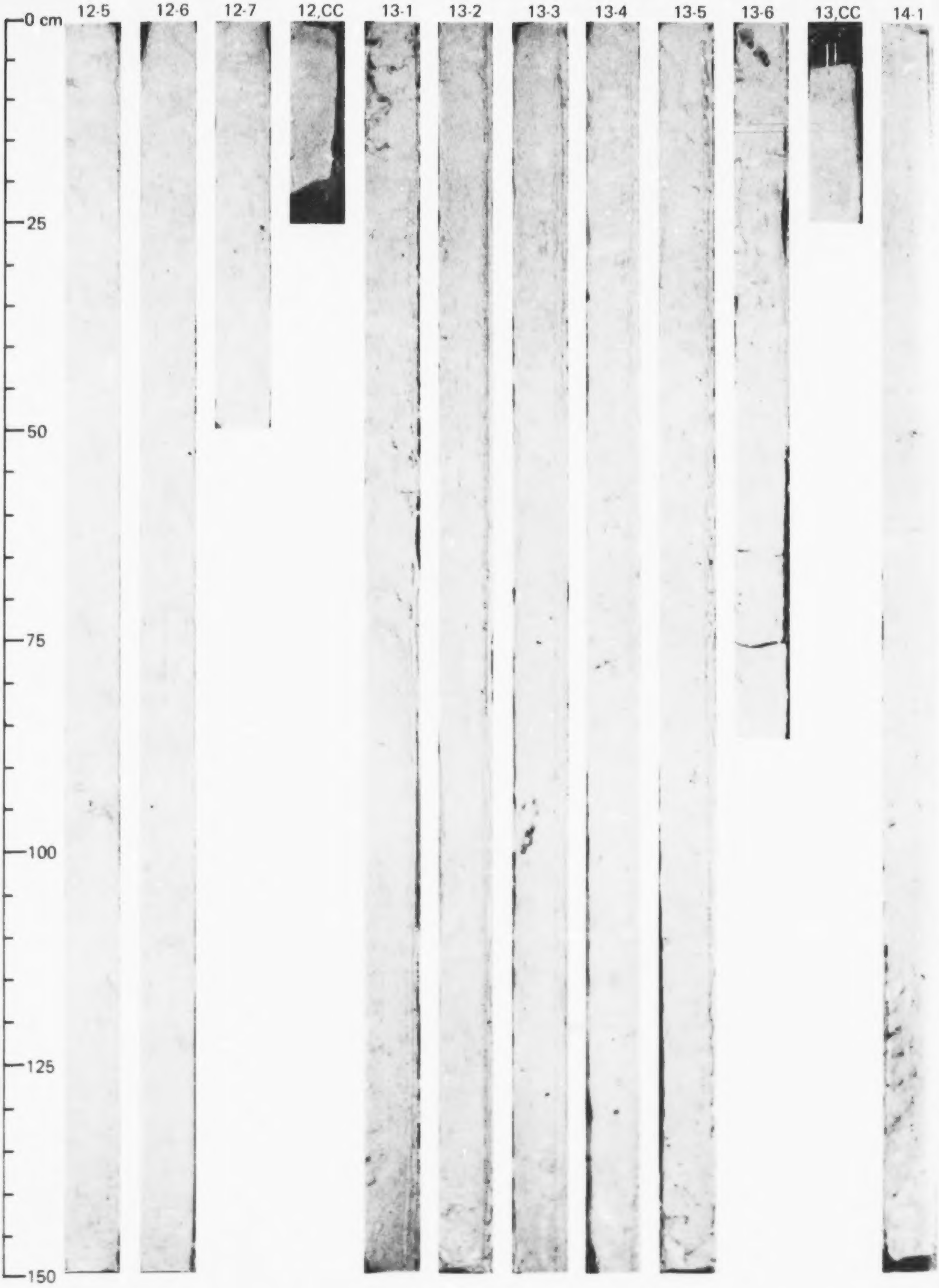

0 cm
25
50
75
100
125
150
4-5
4-6
4-7
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5,CC


6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4
0 cm
25
50
75
100
125
150

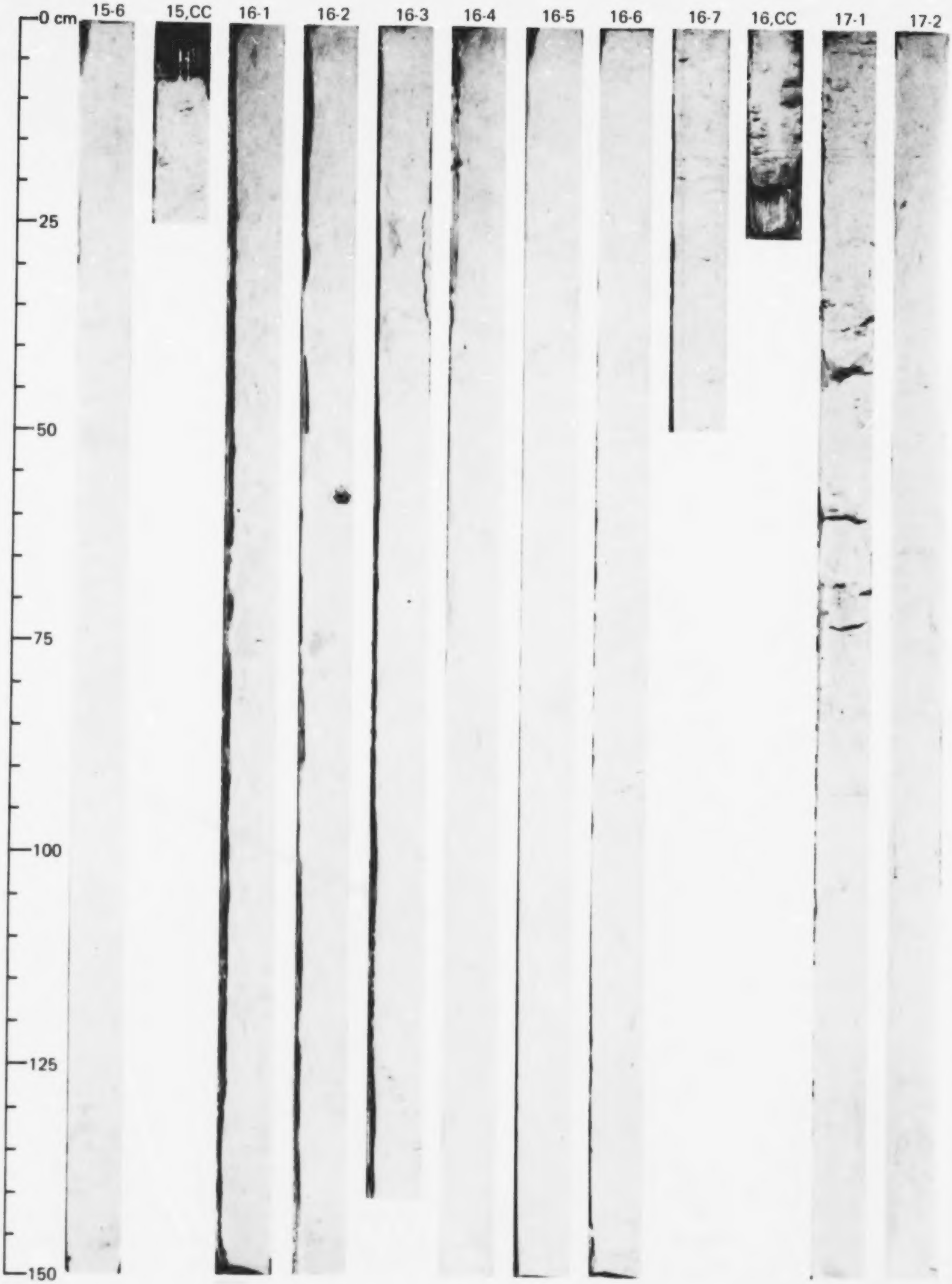

7-5
7,CC
8-1
8-2
8-3
8-4
8-5
8-6
8,CC
9-1
9-2
9-3
0 cm
25
50
75
100
125
150

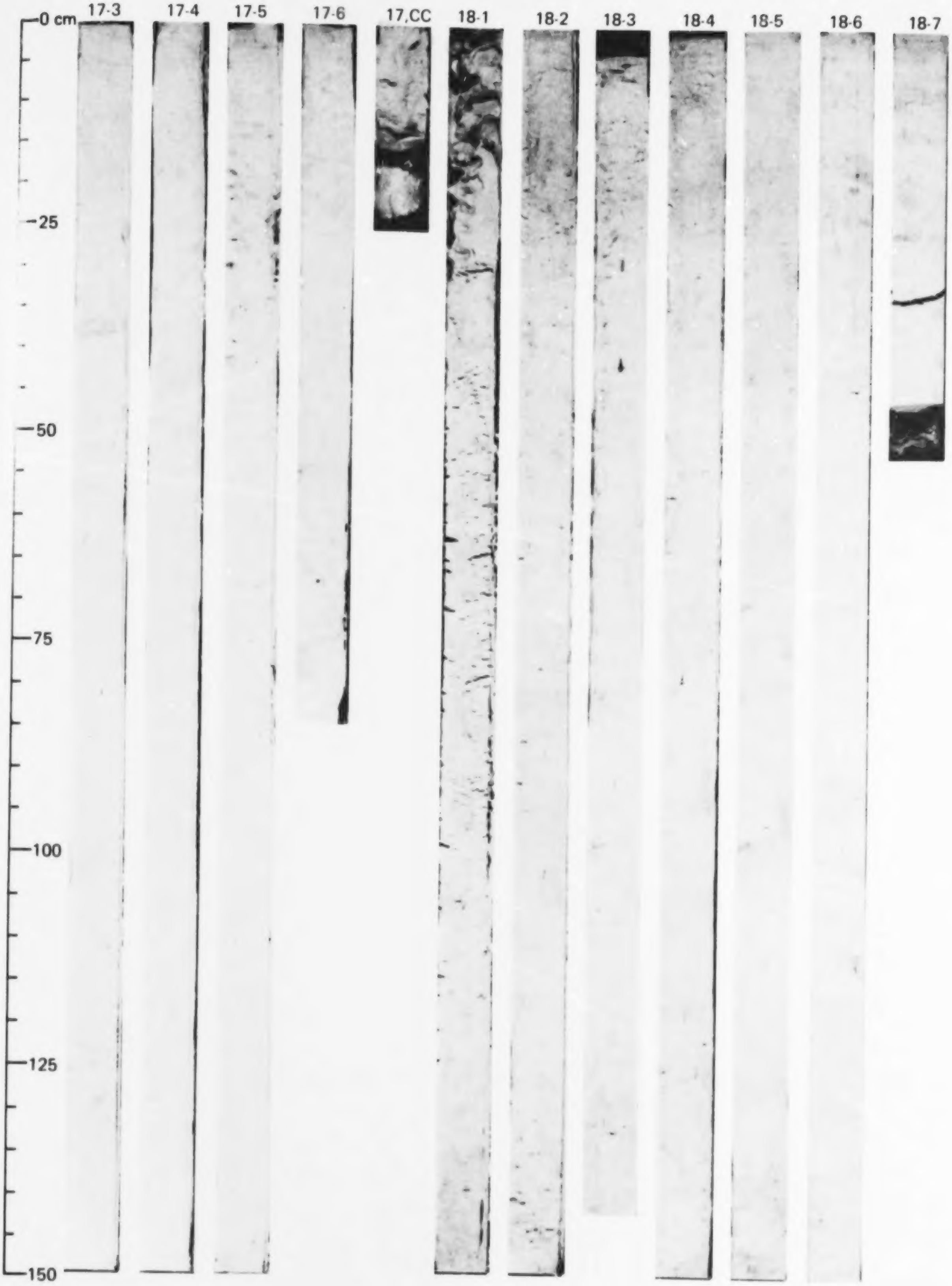

9-4
9-5
9-6
9-7
9,CC
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0 cm
25
50
75
100
125
150

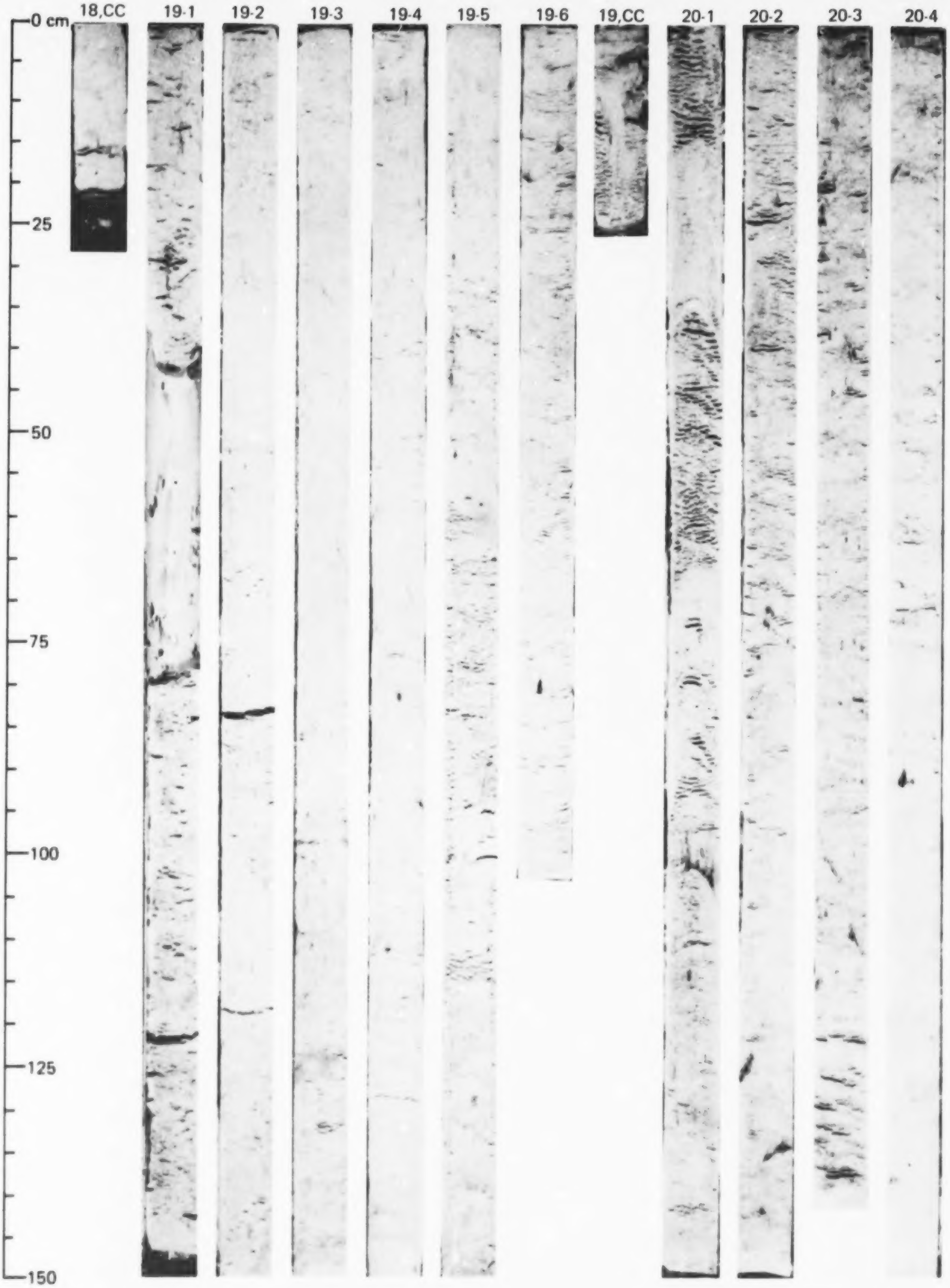

0 cm
25
50
75
100
125
150
10,CC
11-1
11-2
11-3
11-4
11-5
11-6
11,CC
12-1
12-2
12-3
12-4

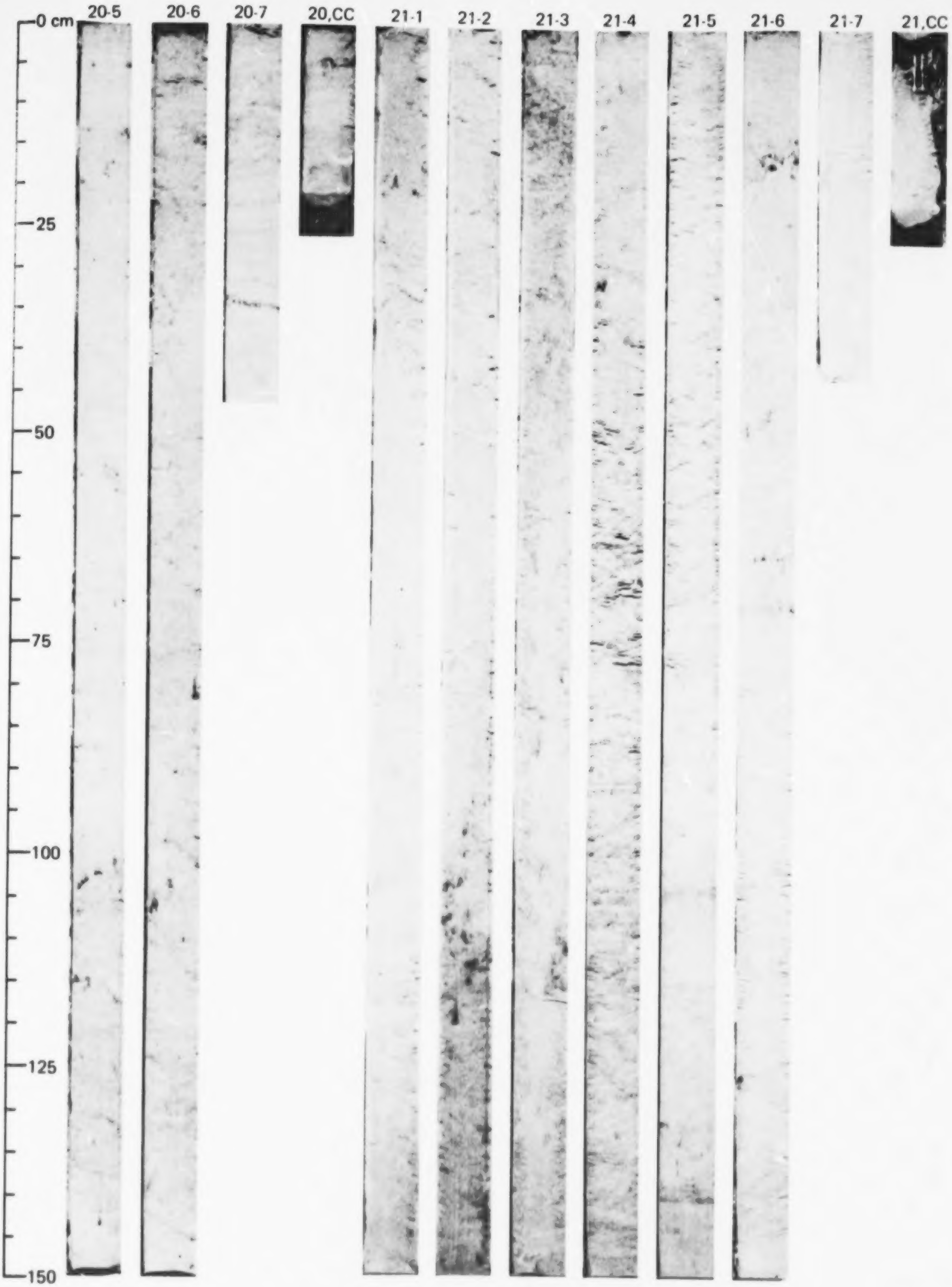

0 cm
25
50
75
100
125
150
12-5
12-6
12-7
12,CC
13-1
13-2
13-3
13-4
13-5
13-6
13,CC
14-1

0 cm
25
50
75
100
125
150
14-2
14-3
14-4
14-5
14-6
14-7
14,CC
15-1
15-2
15-3
15-4
15-5

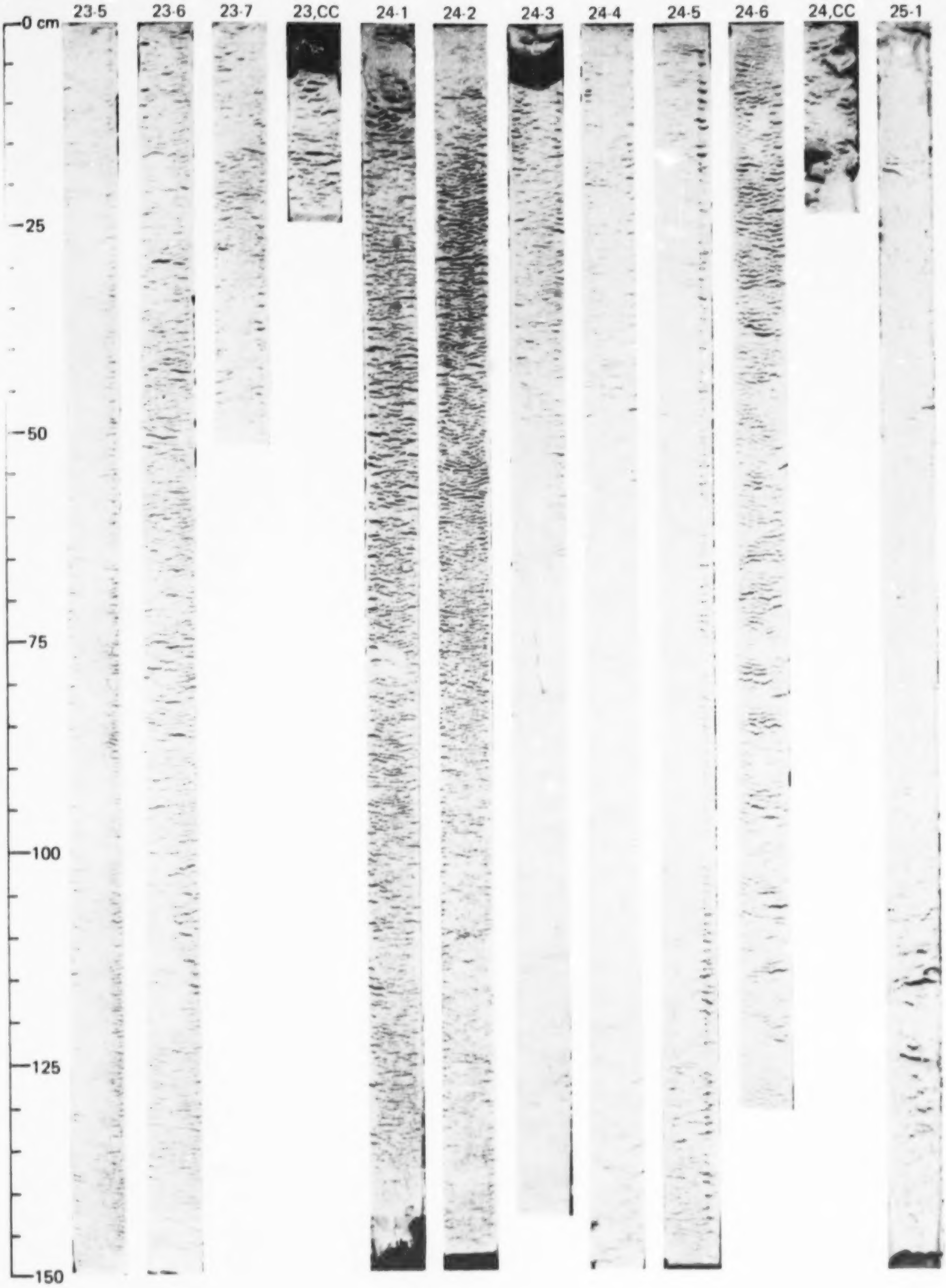

0 cm
25
50
75
100
125
150
15-6
15,CC
16-1
16-2
16-3
16-4
16-5
16-6
16-7
16,CC
17-1
17-2

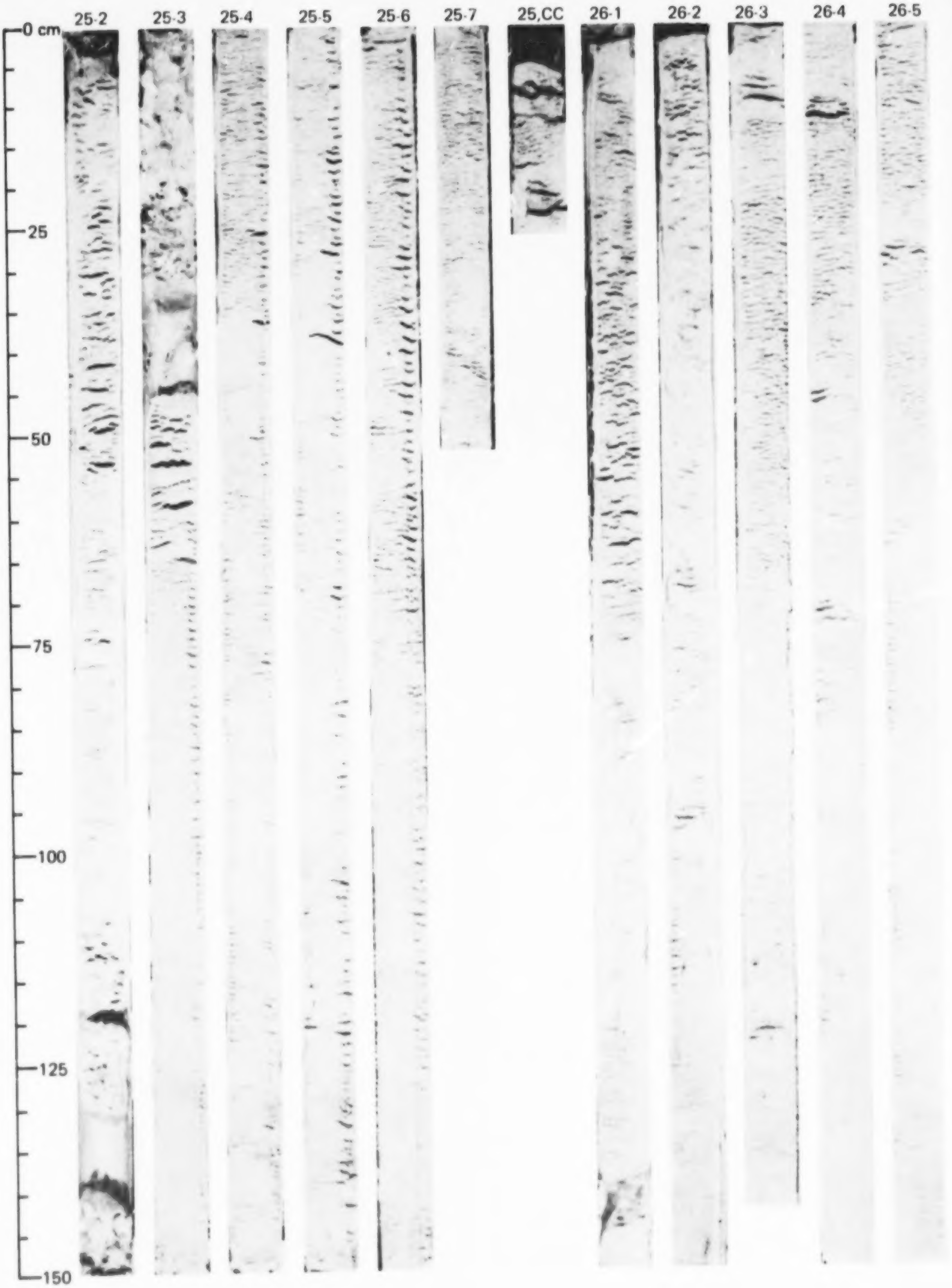

0 cm
25
50
75
100
125
150
17-3
17-4
17-5
17-6
17,CC
18-1
18-2
18-3
18-4
18-5
18-6
18-7

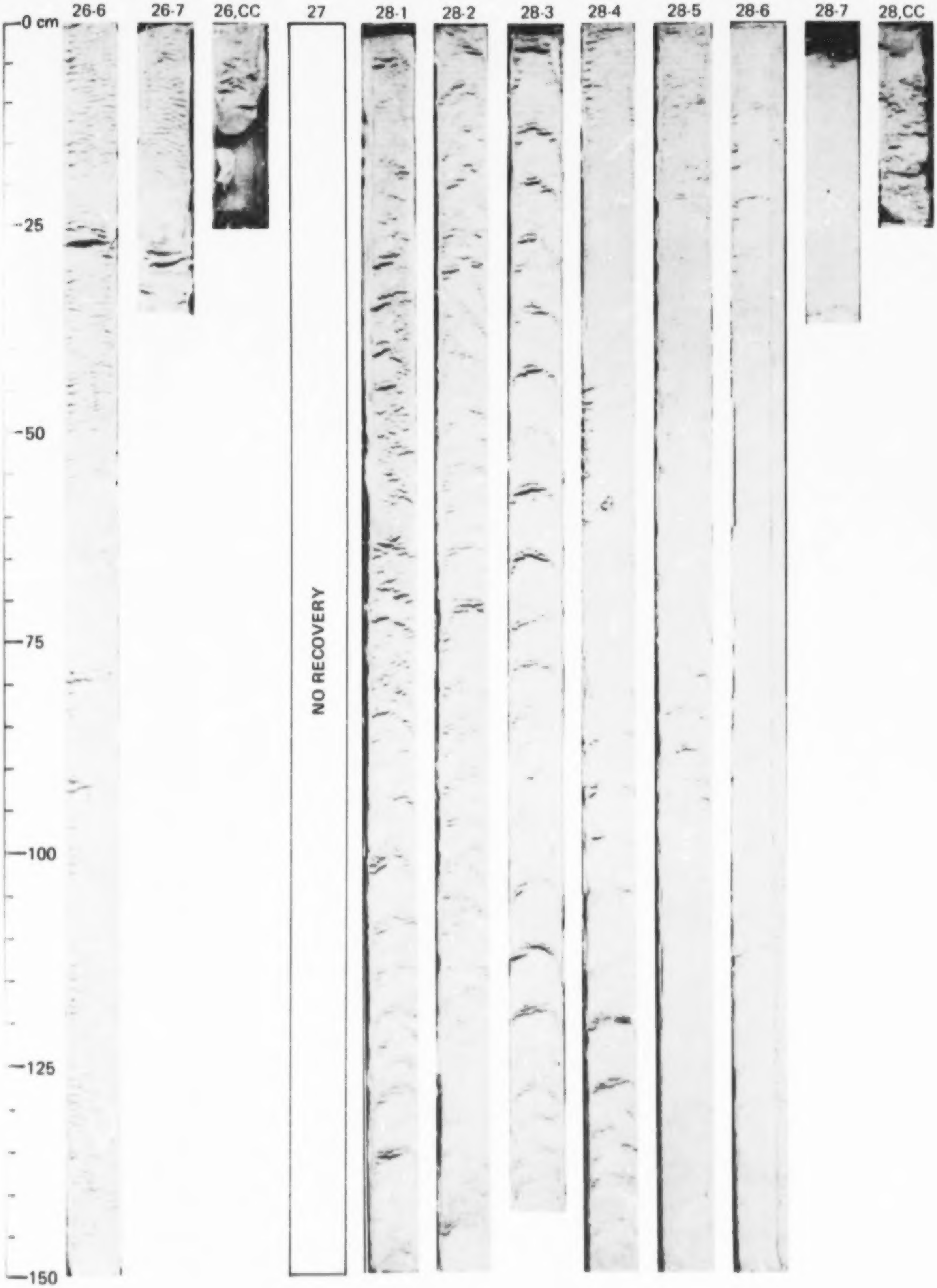

18,CC
19-1
19-2
19-3
19-4
19-5
19-6
19,CC
20-1
20-2
20-3
20-4
0 cm
25
50
75
100
125
150

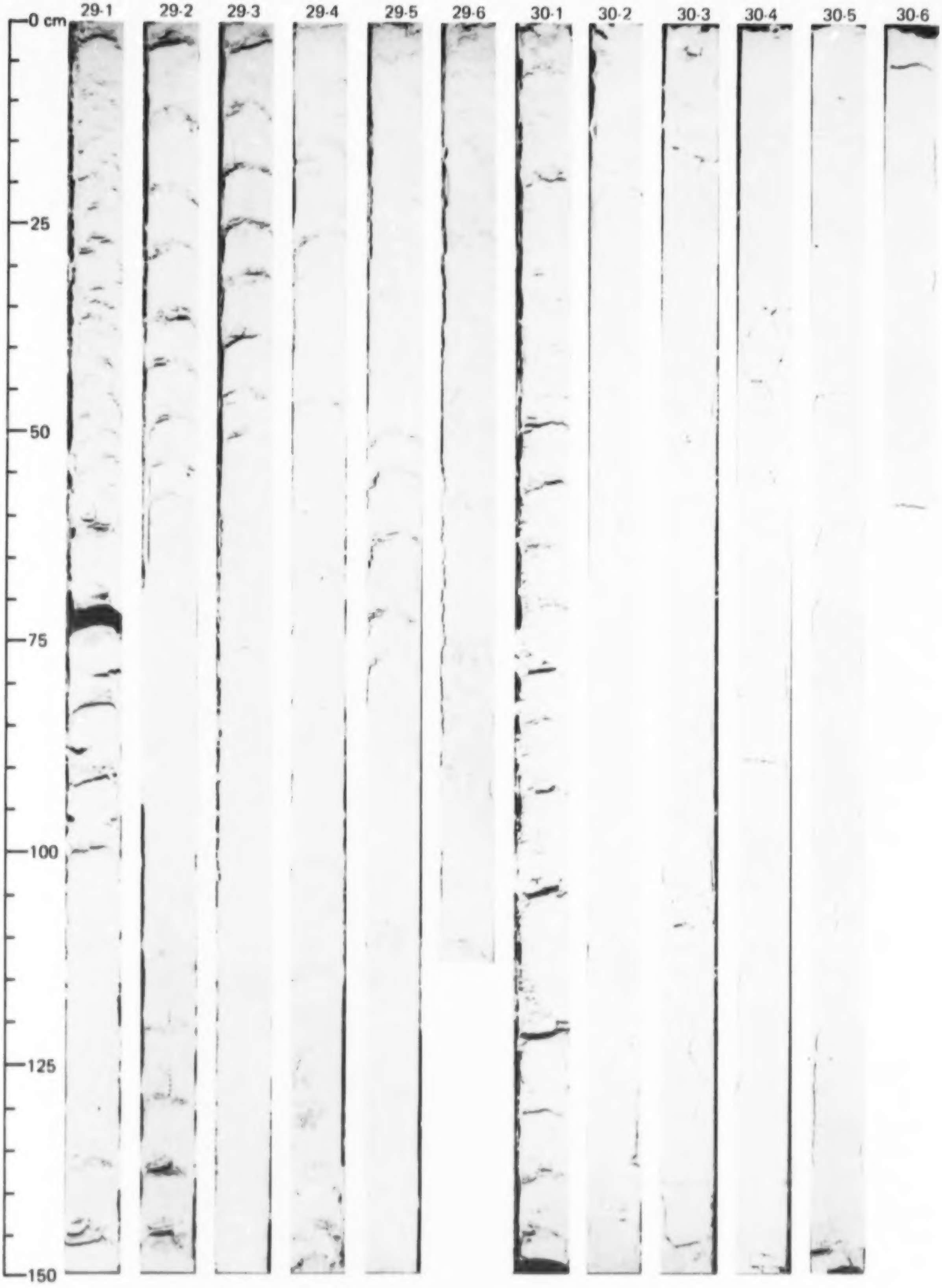

0 cm
25
50
75
100
125
150
20-5
20-6
20-7
20,CC
21-1
21-2
21-3
21-4
21-5
21-6
21-7
21,CC

22-1
22-2
22-3
22-4
22-5
22-6
22-7
22,CC
23-1
23-2
23-3
23-4
0 cm
25
50
75
100
125
150


23-5
23-6
23-7
23,CC
24-1
24-2
24-3
24-4
24-5
24-6
24,CC
25-1
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
25-2
25-3
25-4
25-5
25-6
25-7
25,CC
26-1
26-2
26-3
26-4
26-5


26-6
26-7
26,CC
27
28-1
28-2
28-3
28-4
28-5
28-6
28-7
28,CC
0 cm
25
50
75
100
125
150
NO RECOVERY


29-1
29-2
29-3
29-4
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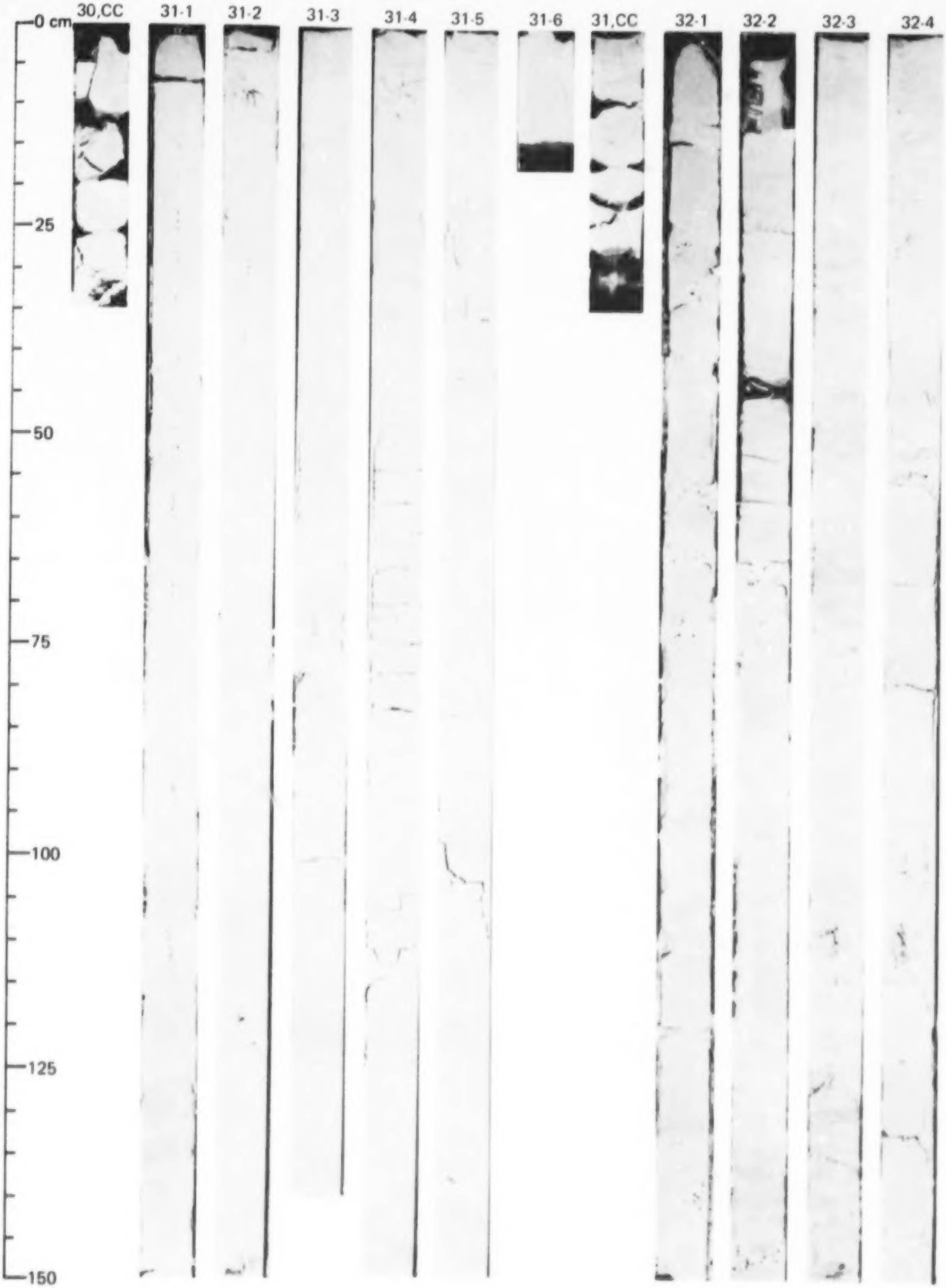
50
75
100
125
150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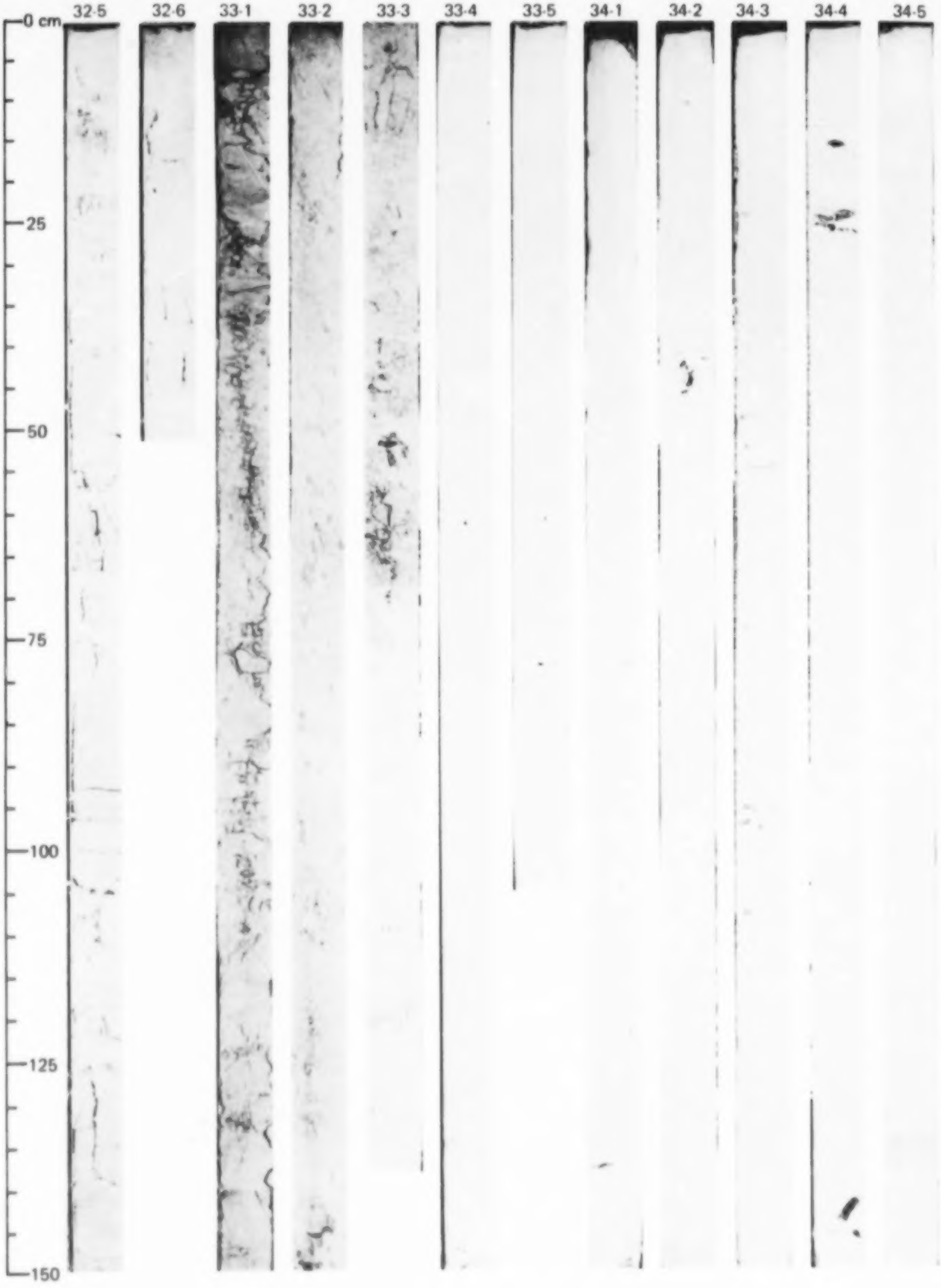
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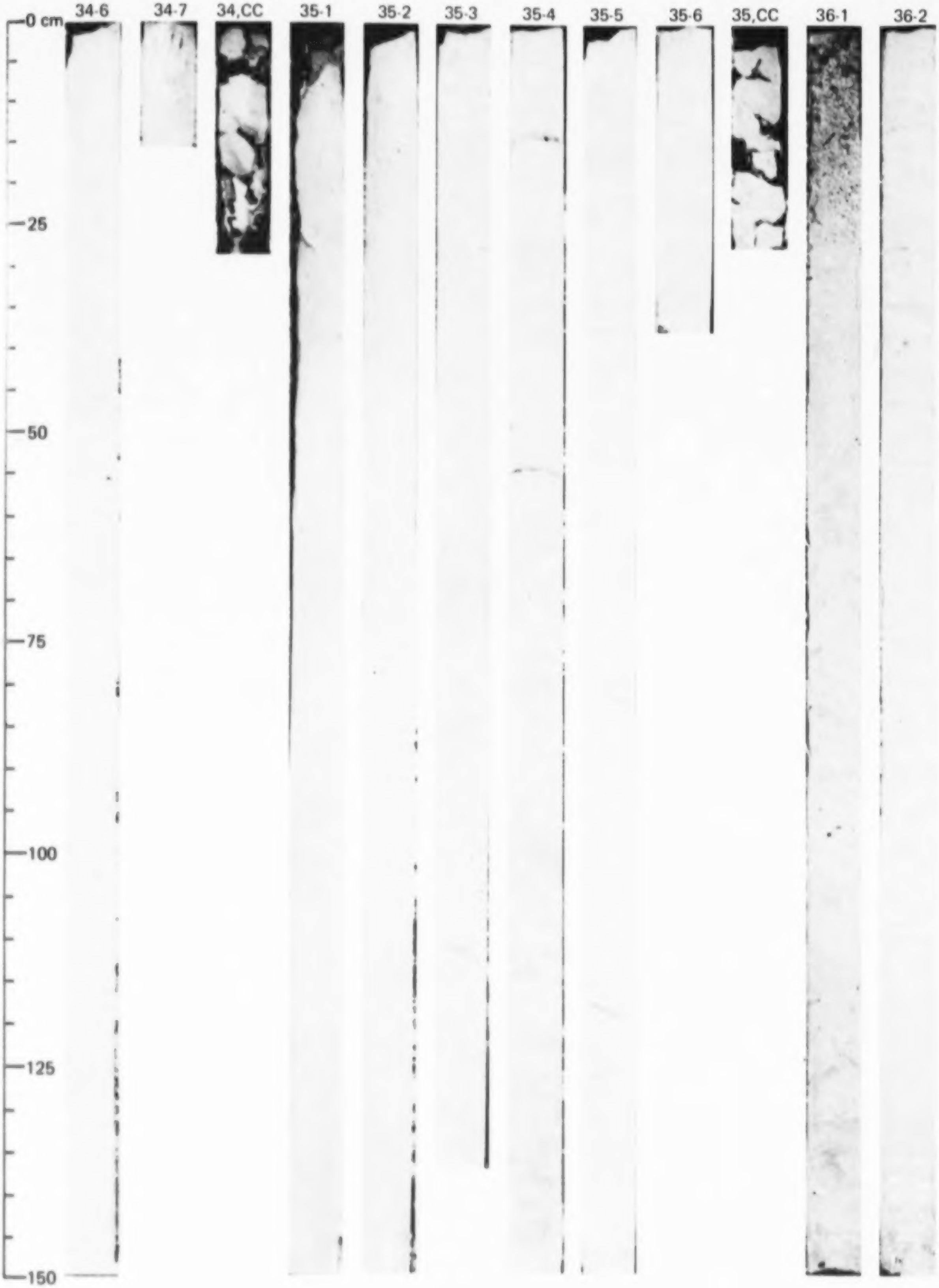

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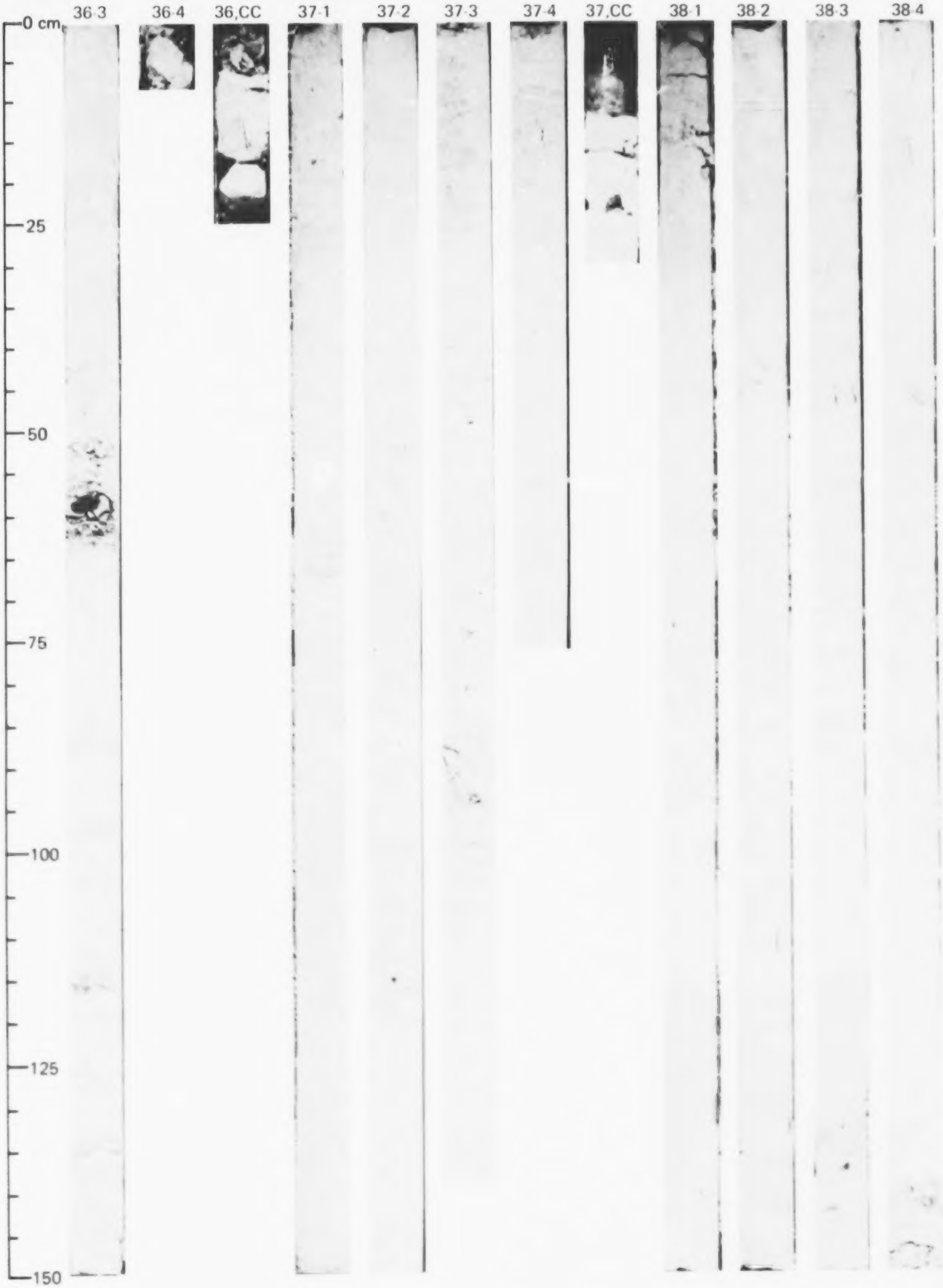
36-1
36-2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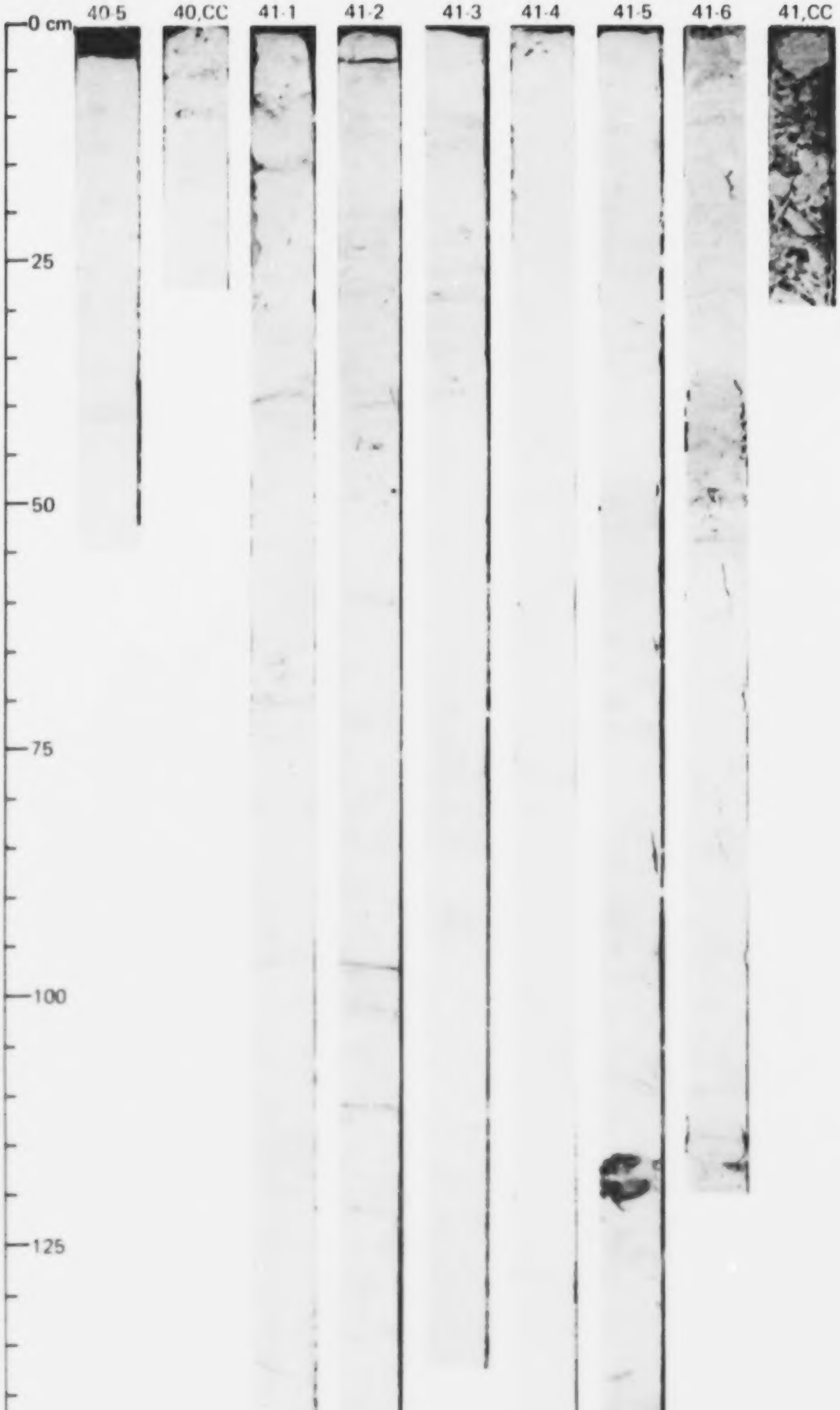
37-1
37-2
37-3
37-4
37,CC
38-1
38-2
38-3
38-4
0 cm
25
50
75
100
125
150

0 cm
25
50
75
100
125
150
38-5
38-6
38,CC
39-1
39-2
39-3
39-4
39,CC
40-1
40-2
40-3
40-4


40-5
40,CC
41-1
41-2
41-3
41-4
41-5
41-6
41,CC
0 cm
25
50
75
100
125
150

9. SITE 593: CHALLENGER PLATEAU[1]

Shipboard Scientific Party[2]

HOLE 593

ate occupied: 28 December 1982

ate departed: 30 December 1982

me on hole: 2 days, 16 hr.

sition: 40°30.47′S; 167°40.47′E

ater depth (sea level; corrected m, echo-sounding): 1068

ater depth (rig floor; corrected m, echo-sounding): 1078

ottom felt (m, drill pipe): 1079

enetration (m): 571.5

umber of cores: 60

otal length of cored section (m): 571.5

otal core recovered (m): 468.21

ore recovery (%): 81.9

ldest sediment cored:
Depth sub-bottom (m): 571.5
Nature: Nannofossil chalk
Age: Late Eocene
Measured velocity (km/s): 2.340 km/s at 554 m

Basement: Not reached

HOLE 593A

Date occupied: 30 December 1982

Date departed: 1 January 1983

Time on hole: 25 hr.

Position: 40°30.47′S; 167°40.47′E

Water depth (sea level; corrected m, echo-sounding): 1068

Water depth (rig floor; corrected m, echo-sounding): 1078

Bottom felt (m, drill pipe): 1080.3

Penetration (m): 496.8

Number of cores: 27

Total length of cored section (m): 257.3

Total core recovered (m): 227.71

Core recovery (%): 88.5

Oldest sediment cored:
Depth sub-bottom (m): 496.8
Nature: Nannofossil chalk
Age: Latest Oligocene

Basement: Not reached

Principal results: Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau. The western part of the Challenger Plateau provides a shallow-water pedestal of 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed accumulation of an uncomplicated Paleogene-Neogene pelagic ooze sequence with virtually no terrigenous sedimentary influences. Site 593 is a reoccupation of Site 284, cored during Leg 29 of DSDP.

Site 593 consists of two holes continuously cored to a maximum sub-bottom depth of 571.5 m. Hole 593 was cored with the hydraulic piston corer (HPC) from 0 to 245.1 m sub-bottom and continued to a total depth of 571.5 m with the extended core barrel (XCB). Hole 593A was continuously cored with the HPC from 0 to 209.3 m sub-bottom, then washed down to 448.8 m and cored with the XCB to 496.8 m to recover the Oligocene/Miocene transition. This interval was poorly cored in the first hole.

Site 593 is an apparently continuous stratigraphic sequence from the late Eocene (42 m.y.) to the Quaternary. A paleomagnetic polarity stratigraphy has been identified to the middle of the Gauss Chron (3.2 m.y.).

The general facies is a foraminiferal-bearing nannofossil ooze that grades into nannofossil ooze and nannofossil chalk with depth. Only traces of biosiliceous sediments occur in a few intervals. The section has been divided into two units of earliest Oligocene to Recent age.

Unit I is subdivided into four units:

Subunit IA, of late Quaternary age, represents a veneer (0–6 m) of yellow gray foraminifer-bearing nannofossil ooze within the oxidized zone near the seafloor.

Subunit IB, a thick (6–393 m) sequence of Quaternary to middle Miocene age, is a rather monotonous light-colored foraminifer-bearing nannofossil ooze to nannofossil ooze.

Subunit IC, a thin (393 to 418 m) early middle Miocene sequence, is an oxidized sediment zone of pale orange color.

Subunit ID, is a thick (418 to 545.5 m) sequence of nannofossil ooze of early middle Miocene to earliest Oligocene age.

Unit II is a thin (545.5 to 571.5 m) sequence of lithified volcanogenic turbidites and pyroclastics emplaced at the Eocene/Oligocene boundary and probably derived from nearby "Lalitha Pinnacle." The volcanogenic rocks are underlain by nannofossil chalk at the base of the hole. This chalk contains many thin laminae of altered volcanic glass, indicating an episode of active explosive volcanism.

Site 593 is a fine, complete stratigraphic succession in southern temperate waters with abundant, well-preserved planktonic foraminifers except in the volcanogenic material. Calcareous nannofossils are abundant throughout, but not well preserved below the Pliocene. An excellent succession of the benthic foraminifers is preserved.

Planktonic foraminiferal zonations are typically temperate in character. A number of calcareous nannofossil zones are missing because the warm-water marker forms are rare or absent. All epoch boundaries are well represented between the Eocene/Oligocene and the Pliocene/Pleistocene boundaries. The Oligocene/Miocene boundary coincides with a more lithified ooze layer. The Eocene/Oligocene boundary coincides with the volcanogenic sequence (Unit II) with no apparent break in sedimentation. Evidence from the seismic profiles suggest that the volcanic rocks resulted from a single episode of submarine extrusion. These volcanics are approximately coeval with extensive volcanism in New Zealand, including the Deborah volcanics of South Canterbury. A number of volcanic pinnacles with seismic character similar to that of "Lalitha Pinnacle" occur over the Challenger Plateau, indicating widespread volcanism at that time.

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[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. ovt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), chool of Earth Sciences, Flinders University of South Australia, Bedford Park, South Ausalia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; harles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narraansett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, O. Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, tony Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National Histoire Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Scinces Division, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 6720; James V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 45 Middlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Scinces, Open University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United ingdom; William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, ittleton, CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgangoethe Universitat, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic Germany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Oceanogaphy, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, ollege Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Scinces, Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. eological Survey, Denver Federal Center, Denver, CO 80225); Campbell S. Nelson, Departnent of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Chrisan Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 3288 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu niversity, Varanasi 221 005, India; Rudiger Stein, Geologisch-Paläontologisches Institut, niversitat Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petroum and Organic Geochemistry (ICH-5), Kernforschungslage Julich GmbH, P.O. Box 1913, 170 Julich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, aculty of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

The middle Miocene oxidized ooze (Subunit IC) was deposited between 15.5 and 15 m.y., immediately preceding the time of major ice-sheet growth on east Antarctica. It is, therefore, possible that it reflects important paleoceanographic changes at an oceanographic front in the Southern Ocean tied to this glacial evolution. The oxidized sediment contains a temporary benthic foraminiferal fauna that is typical of oxygen-rich waters.

The late early Pliocene (4-3 m.y.) is marked, as in other Leg 90 sites, by an episode when enhanced carbonate productivity caused extremely high sedimentation rates.

BACKGROUND AND OBJECTIVES

Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau (Figs. 1 and 2). The Challenger Plateau is effectively a topographic extension of the Lord Howe Rise and its western part provides a shallow-water pedestal 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed the accumulation of an uncomplicated sequence of Neogene pelagic ooze with virtually no terrigenous sedimentary influences.

Site 593 is a reoccupation of Site 284, which was cored during Leg 29 of the Deep Sea Drilling Project in April, 1973 (Kennett, Houtz, et al., 1975). Site 284 was added very near the end of Leg 29 when it became apparent that two spare days could be made available for an additional site. Because no formal safety panel reviews had been made, coring was restricted to the upper 208 m lest hydrocarbons occur below this depth. Site 284 is a valuable middle late Miocene to Quaternary sequence of calcareous oozes, located in cool-temperate waters. The site has provided material for a wide variety of paleoceanographic and biostratigraphic studies (e.g. Shackleton and Kennett, 1975; Kennett and Vella, 1975; Kennett et al., 1979; Hornibrook, 1982).

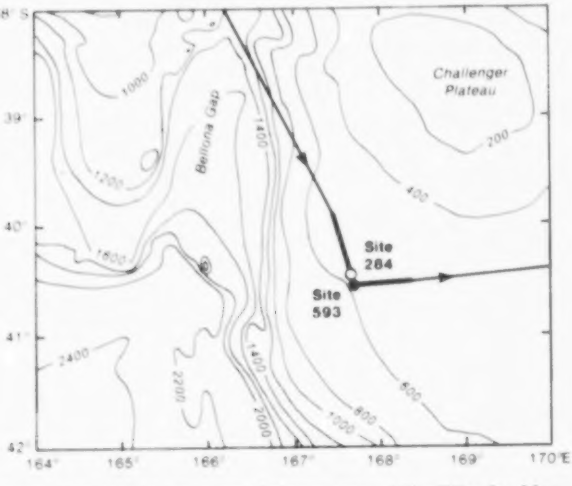


Figure 1. Regional bathymetry (fathoms) around Site 593; after Mammerickx et al. (1974); *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

Because Site 284 had been shown to contain an excellent late Neogene section, is was decided to recore this location using the HPC and the XCB. It was hoped that a pair of hydraulic piston cores would provide a better-quality sequence for higher-resolution biostratigraphic and paleoceanographic studies. Also the section needed to be extended to include as much of the Neogene as possible. The seismic profile record (Fig. 2) shows that the first distinct reflector lies at about 500 m. This may be the regional Eocene/Oligocene hiatus (or Oligocene/Miocene, as at Site 592). Therefore a major objective at Site 593 was to core the entire Neogene sequence. Because sedimentation rates were known to be high (about 40 m/m.y.) at this location, this sequence was expected to provide material for high-resolution stratigraphic studies.

Site 593 is located in the present-day cool-temperate water mass, about midway between transitional water masses north of New Zealand and subantarctic waters to the south. That this lies within the west wind drift was made apparent by a population of about 70 albatrosses that welcomed our ship when it reached the roaring forties!

Significant paleoceanographic changes have been documented for this latitude (Kennett and Vella, 1975; Shackleton and Kennett, 1975) although no major water mass boundary migrated across the location of Site 284 during the late Neogene. All documented paleoceanographic oscillations have been confined within the temperate water mass.

The scientific objectives of Site 593 were much the same as the other sites in the southwest Pacific latitudinal traverse: to understand, using a variety of analytical approaches, the Neogene paleoceanographic evolution of the South Pacific and its relations with global paleoenvironmental change; to develop a tephrochronology and to study the diagenetic history of the sediment column.

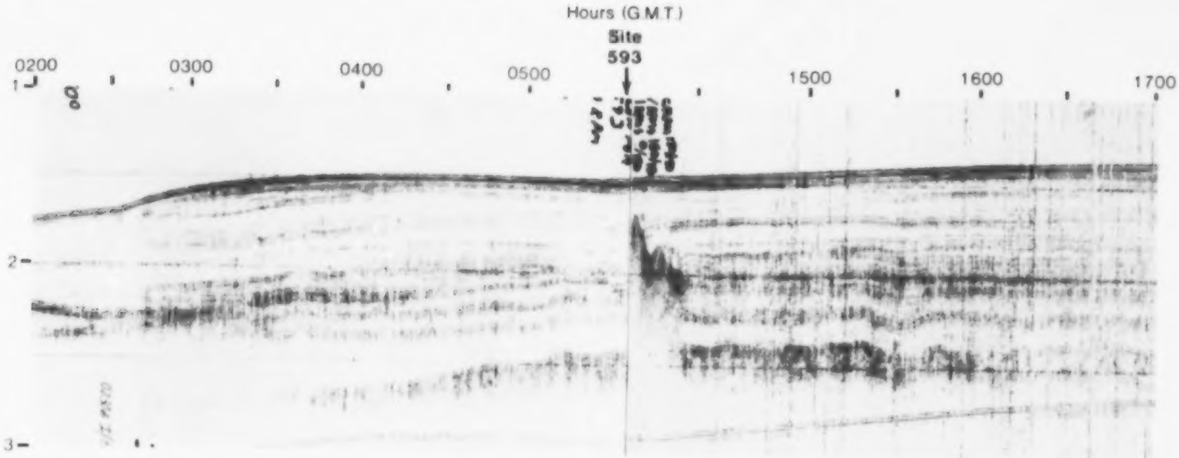
OPERATIONS

Site 592 to Site 593

The pipe was pulled out of the hole, the rig floor made secure for sea, and the vessel was under way for Site 593 at 1242 hr., 27 December. The trip south was made in pleasant weather. As had become customary, a direct approach was made and the 13.5 kHz beacon was dropped on the first pass at 1632 hr., 28 December. The transit took 27.9 hr. and covered 264.8 n. mi. at an average 9.5 knots.

Site 593 (SW-2): Challenge Plateau

The routine short hook-up BHA for both XCB and variable length (VL)HPC work was made up and run to the shoot-off point for the first piston core attempt. A good mudline core was recovered, establishing the water



gure 2. Water gun profile (*Glomar Challenger*) near Site 593; bandpass filter 40–160 Hz.

epth at 1079 m, thus spudding Hole 593 at 2155 hr., 28 ecember (Table 1).

Using the 9.5-m VLHPC with two shear pins, coring rogressed easily through unusually soft carbonate ooze. ull stroke of the piston corer was achieved on all cores. At Core 593-22 (206.7 m BSF) a crumpled liner indicated that the adhesive properties of the sediment were becoming significant. Two cores later the barrel could not be withdrawn with 30,000 lb. overpull and was partially washed over to free it; piston coring was then terminated.

The XCB coring tools were then rigged up and deployed. After some initial fine-tuning on the troublesome XCB latch good results were achieved for the next 24 cores.

At Core 593-49 shattered liners reappeared. In each off-numbered core of the next three, recovery was marginal because the liner was shattered, which suggested that one of the two XCB tools being alternated was faulty. However, no obvious problem was discovered. To deal with the problem, the remaining cores in the hole were taken by running the XCB tools in on the wire line. By this means good cores with liners intact were achieved or the rest of the hole. Core 593-51 became stuck in the pipe before reaching the bit and could not be worked oose with the wire line until after the interval had been rilled, so no core was recovered.

Starting with Core 593-58 at about 550 m BSF, a 10-m nterval of very hard volcanogenic turbidites was encountered and was cored successfully using the XCB soft-formation cutting shoes.

The hole was terminated at 571.5 m BSF when the ediments of the Eocene objective were reached.

The bit was pulled to the mudline and the vessel offset 100 ft. north by 100 ft. west in preparation for the repeat piston core sequence.

Hole 593A

Hole 593A was spudded with a mudline piston core t 2337 hr., 30 December (Table 1). Piston coring continued as in the previous hole with no difficulties at all up to Core 593A-22 at 209.3 m BSF. At this point no further cores in the piston corer "zone" were desired. Next the XCB was deployed and washed to 448.8 m BSF in order to recover the section which lost during the interlude of shattered liners and associated poor recovery in the first hole. Each of the five XCB cores was taken by running in on the wire line. Recovery was good through the boundary except for Core 593A-24 which, apparently, suffered a slight blockage and recovered only 3.15 m. The hole was terminated after the fifth XCB core at a total depth of 496.8 m BSF. The pipe was then pulled out of the hole and the bit arrived on deck just 15 min. after the start of the New Year, 1983.

LITHOSTRATIGRAPHY

The sequence recovered at Site 593 represents two lithostratigraphic units. Unit I has been subdivided into four subunits based on color and composition (Table 2).

Unit I

The general facies of Site 593 is a foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze and a nannofossil chalk with depth. The transition to reduced abundances of foraminifers, from about 15 to about 5% (smear-slide estimates only), occurs around 110 m sub-bottom depth. The facies is predominantly calcareous nannofossils with very subordinate foraminifers. Other components, such as quartz and feldspar grains, volcanic glass, and pyrite(?), only occur in trace abundances (<1%) (Fig. 3). Micritic carbonate occurs in persistent abundances of 5 to 10% from 323 m sub-bottom to total depth, but the sediment does not become chalk until 562 m. The only biogenic silica found were traces (less than 1%) of sponge spicules in a zone from about 249 to 296 m sub-bottom.

Subunit IA (Hole 593: 0–1.5 m; Hole 593A: 0–6 m; late Quaternary)

This subunit recognized by its yellowish gray (5Y 7/2) color, is foraminifer-bearing nannofossil ooze. The contact with underlying Subunit IB is gradational over about

Table 1. Coring summary, Site 593.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 593							
1	28	2220	1079.9-1085.0	0.0-5.1	5.1	5.09	99.8
2	28	2300	1085.0-1094.6	5.1-14.7	9.6	8.81	91.7
3	28	2348	1094.6-1104.2	14.7-24.3	9.6	9.21	95.9
4	29	0035	1104.2-1113.8	24.3-33.9	9.6	8.86	92.2
5	29	0100	1113.8-1123.4	33.9-43.5	9.6	9.02	93.9
6	29	0135	1123.4-1133.0	43.5-53.1	9.6	9.11	94.9
7	29	0210	1133.0-1142.6	53.1-62.7	9.6	9.22	96.0
8	29	0255	1142.6-1152.2	62.7-72.3	9.6	3.11	32.3
9	29	0340	1152.2-1161.8	72.3-81.9	9.6	8.17	85.1
10	29	0355	1161.8-1171.4	81.9-91.5	9.6	0.0	0.0
11	29	0425	1171.4-1181.0	91.5-101.1	9.6	7.75	80.7
12	29	0500	1181.0-1190.6	101.1-110.7	9.6	9.52	99.1
13	29	0540	1190.6-1200.2	110.7-120.3	9.6	9.39	97.3
14	29	0615	1200.2-1209.8	120.3-129.9	9.6	9.45	98.4
15	29	0635	1209.8-1219.4	129.9-139.5	9.6	9.41	98.0
16	29	0720	1219.4-1229.0	139.5-149.1	9.6	9.38	97.7
17	29	0800	1229.0-1238.6	149.1-158.7	9.6	9.51	99.0
18	29	0830	1238.6-1248.2	158.7-168.3	9.6	8.93	93.0
19	29	0910	1248.2-1257.8	168.3-177.9	9.6	9.67	100+
20	29	0945	1257.8-1267.4	177.9-187.5	9.6	9.52	99.1
21	29	1015	1267.4-1277.0	187.5-197.1	9.6	9.70	100+
22	29	1115	1277.0-1286.6	197.1-206.7	9.6	6.13	64
23	29	1200	1286.6-1296.2	206.7-216.3	9.6	9.61	100+
24	29	1250	1296.2-1305.8	216.3-225.9	9.6	9.18	96
25	29	1410	1305.8-1315.4	225.9-235.5	9.6	9.54	99
26	29	1500	1315.4-1325.0	235.5-245.1	9.6	8.48	88
27	29	1550	1325.0-1334.6	245.1-254.7	9.6	9.69	100+
28	29	1650	1334.6-1344.2	254.7-264.3	9.6	7.87	82
29	29	1730	1344.2-1353.8	264.3-273.9	9.6	7.88	82
30	29	1800	1353.8-1363.4	273.9-283.5	9.6	7.12	74
31	29	1840	1363.4-1373.0	283.5-293.1	9.6	7.45	78
32	29	1925	1373.0-1382.6	293.1-302.7	9.6	6.80	71
33	29	1945	1382.6-1392.2	302.7-312.3	9.6	7.08	74
34	29	2100	1392.2-1401.8	312.3-321.9	9.6	6.36	66
35	29	2145	1401.8-1411.4	321.9-331.5	9.6	6.92	72
36	29	2230	1411.4-1421.0	331.5-341.1	9.6	5.53	58
37	29	2320	1421.0-1430.6	341.1-350.7	9.6	6.64	69
38	30	0030	1430.6-1440.2	350.7-360.3	9.6	9.46	98
39	30	0115	1440.2-1449.8	360.3-369.9	9.6	8.86	92
40	30	0200	1449.8-1459.4	369.9-379.5	9.6	7.91	82
41	30	0240	1459.4-1469.0	379.5-389.1	9.6	9.71	100+
42	30	0335	1469.0-1478.6	389.1-398.7	9.6	8.53	89
43	30	0400	1478.6-1488.2	398.7-408.3	9.6	9.15	95
44	30	0530	1488.2-1497.8	408.3-417.9	9.6	8.77	91
45	30	0615	1497.8-1507.4	417.9-427.5	9.6	9.75	100+
46	30	0700	1507.4-1517.0	427.5-437.1	9.6	9.65	100+
47	30	0755	1517.0-1526.6	437.1-446.7	9.6	8.55	89
48	30	0905	1526.6-1536.2	446.7-456.3	9.6	7.96	83
49	30	1000	1536.2-1545.8	456.3-465.9	9.6	0.69	7
50	30	1040	1545.8-1555.4	465.9-475.5	9.6	9.15	95
51	30	1135	1555.4-1565.0	475.5-485.1	9.6	0.0	0
52	30	1235	1565.0-1574.6	485.1-494.7	9.6	4.99	52
53	30	1335	1574.6-1584.2	494.7-504.3	9.6	5.01	52
54	30	1435	1584.2-1593.8	504.3-513.9	9.6	7.08	74
55	30	1525	1593.8-1603.4	513.9-523.5	9.6	9.56	100
56	30	1620	1603.4-1613.0	523.5-533.1	9.6	9.31	97
57	30	1730	1613.0-1622.6	533.1-542.7	9.6	9.62	100+
58	30	1845	1622.6-1632.2	542.7-552.3	9.6	4.21	44
59	30	1955	1632.2-1641.8	552.3-561.9	9.6	6.60	67
60	30	2055	1641.8-1651.4	561.9-571.5	9.6	8.58	89
					571.50	468.21	81.9
Hole 593A							
1	30	2355	1080.3-1088.0	0.0-7.7	7.7	7.66	99.0
2	31	0035	1088.0-1097.6	7.7-17.3	9.6	8.62	89.8
3	31	0115	1097.6-1107.2	17.3-26.9	9.6	6.90	71.9
4	31	0200	1107.2-1116.8	26.9-36.5	9.6	8.61	89.7
5	31	0230	1116.8-1126.4	36.5-46.1	9.6	8.15	84.9
6	31	0320	1126.4-1136.0	46.1-55.7	9.6	9.46	98.5
7	31	0355	1136.0-1145.6	55.7-65.3	9.6	8.55	89.0
8	31	0430	1145.6-1155.2	65.3-74.9	9.6	8.22	85.6
9	31	0510	1155.2-1164.8	74.9-84.5	9.6	9.52	99.1
10	31	0610	1164.8-1174.4	84.5-94.1	9.6	8.88	92.5
11	31	0635	1174.4-1184.0	94.1-103.7	9.6	8.76	91.2
12	31	0730	1184.0-1193.6	103.7-113.3	9.6	8.85	92.1
13	31	0800	1193.6-1203.2	113.3-122.9	9.6	8.83	91.9
14	31	0835	1203.2-1212.8	122.9-132.5	9.6	9.04	94.1
15	31	0920	1212.8-1222.4	132.5-142.1	9.6	8.79	91.5
16	31	1000	1222.4-1232.0	142.1-151.7	9.6	9.14	95.5
17	31	1040	1232.0-1241.6	151.7-161.3	9.6	9.54	99.3
18	31	1110	1241.6-1251.2	161.3-170.9	9.6	9.32	97.0
19	31	1150	1251.2-1260.8	170.9-180.5	9.6	9.36	97
20	31	1250	1260.8-1270.4	180.5-190.1	9.6	9.41	98
21	31	1315	1270.4-1280.0	190.1-199.7	9.6	8.71	91
22	31	1400	1280.0-1289.6	199.7-209.3	9.6	8.79	92
Wash to 448.8 m BSF							
23	31	1755	1529.1-1538.7	448.8-458.4	9.6	6.16	64
24	31	1830	1538.7-1548.3	458.4-468.0	9.6	3.15	33
25	31	1920	1548.3-1557.9	468.0-477.6	9.6	8.19	85
26	31	2007	1557.9-1567.5	477.6-487.2	9.6	7.50	78
27	31	2105	1567.5-1577.1	487.2-496.8	9.6	9.60	100
					257.30	227.71	88.5

Table 2. Lithostratigraphy at Site 593.

Lithologic units	Core Section	Sub-bottom depth (m)	Description	Age
IA	1 1A[a]	0.0-1.5 0.0-6.0	Yellowish gray (oxidized) foraminifer-bearing nannofossil ooze	late Quaternary
IB	2 to 42-3 1A[a] to 27	1.5-393.5 6.0->496.8	Light gray to white foraminifer-bearing nannofossil ooze to nannofossil ooze	late Quaternary to middle Miocene
IC	42-4 to 44	393.8-418.0	Pale orange to yellow gray (oxidized) nannofossil ooze	middle Miocene
ID	45 to 58-2	418.0-545.5	White nannofossil ooze	early middle Miocene to earliest Oligocene
II	58-3 to 60	545.5->571.5	Interbedded lithified volcanogenic turbidites and light greenish gray to white nannofossil chalk	late Eocene

[a] Cores from Hole 593A; All others from Hole 593.

5 cm. Subunit IA represents the upper oxidized lay and correlates with a similar subunit at Sites 586, 588 589, 590, 591, and 592. The relatively high content o foraminifers is probably the result of winnowing.

Subunit IB (593: 1.5–393.5 m; 593A: 6.0 to more than 496.8 m; late Quaternary to middle Miocene)

Subunit IB is a light gray (N6) to white (N9) foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze with depth. It is distinguished by its color from overlying Subunit IA and underlying Subunit IC. Subunit IB is mottled and burrowed and has ubiquitous streaks, blebs, and diffusion bands of iron sulfides(?). Four distinct, very light gray (N5–N7) ash beds are found at 21.5, 27.7, 29.5, and 29.60 m sub-bottom. Unusual pockets of foraminifers and pyrite(?) occur between 15 and 178 m sub-bottom. Small zones of cemented nodules occur between 100 and 110 m sub-bottom. The cement may be either gypsum, found at this same sub-bottom depth at Site 284 (Kennett, Houtz, et al., 1975), or possibly celestite. Numerous very thin (less than 1 mm) laminae of pale green hues (5G) occur throughout this subunit. These thin laminae may represent altered volcanic glass.

Subunit IC (593: 393.8–418.0 m sub-bottom; middle Miocene)

Subunit IC is distinguished from two overlying an underlying subunits by its distinctive pale orange (10Y 8/2) color but is lithologically identical to the surrounding subunits. The upper contact is quite sharp but th lower contact is gradational and varies in color from ver pale orange (10YR 8/2) through yellowish gray (5Y 8/1 to light greenish gray (5GY 8/1) with depth.

Subunit ID (593: 418.0–545.5 m sub-bottom; early middle Miocene to earliest Oligocene)

Subunit ID is a white (N9) nannofossil ooze that i identical in lithology to the lower part of Subunit IB Subunit ID is defined by its stratigraphic position below the easily recognized pale orange Subunit IC.

Between about 475 and 485 m sub-bottom in Hole 593 and about 455 and 468 m sub-bottom in Hole 593A

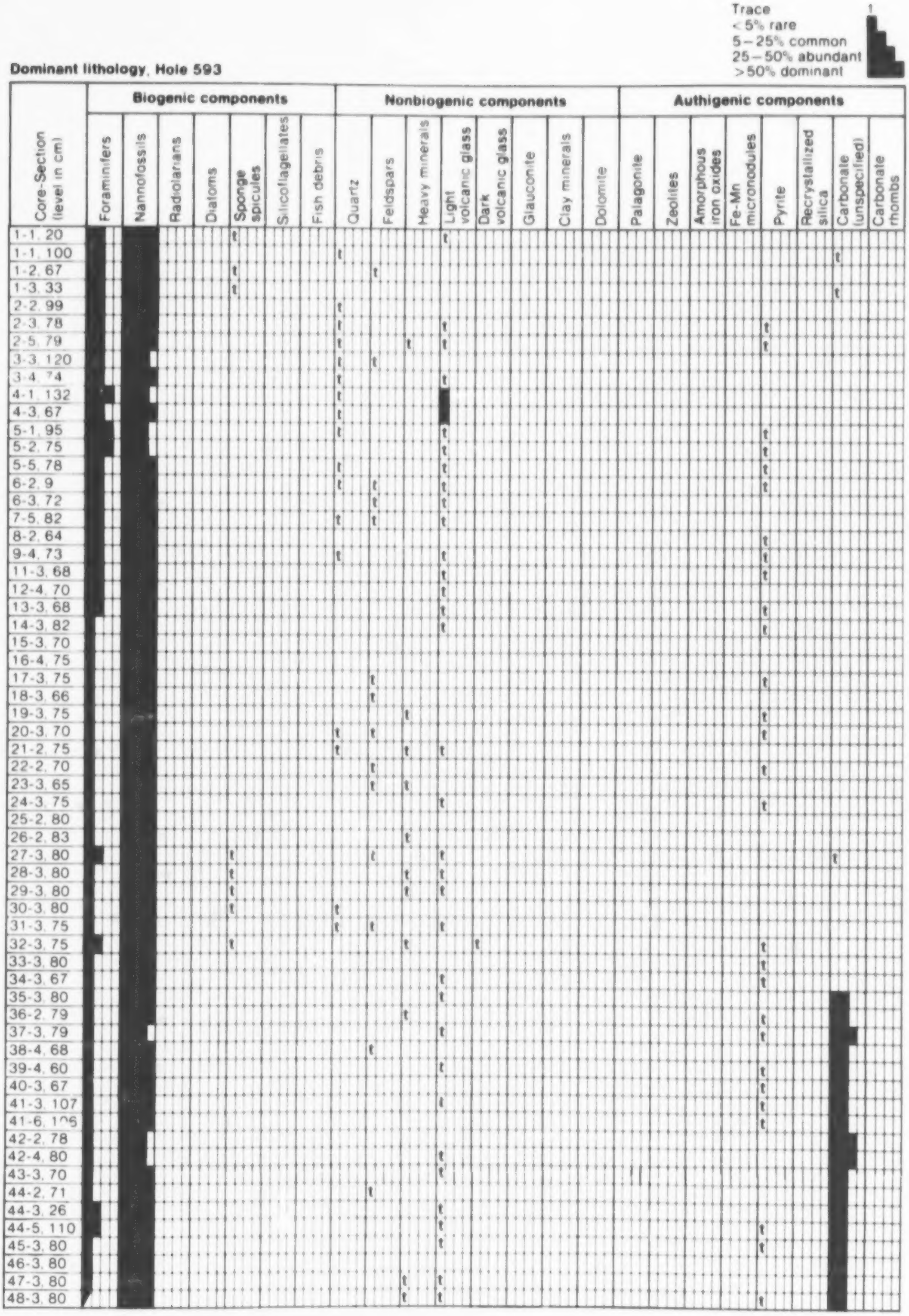


Figure 3. Smear slide summary, Site 593.

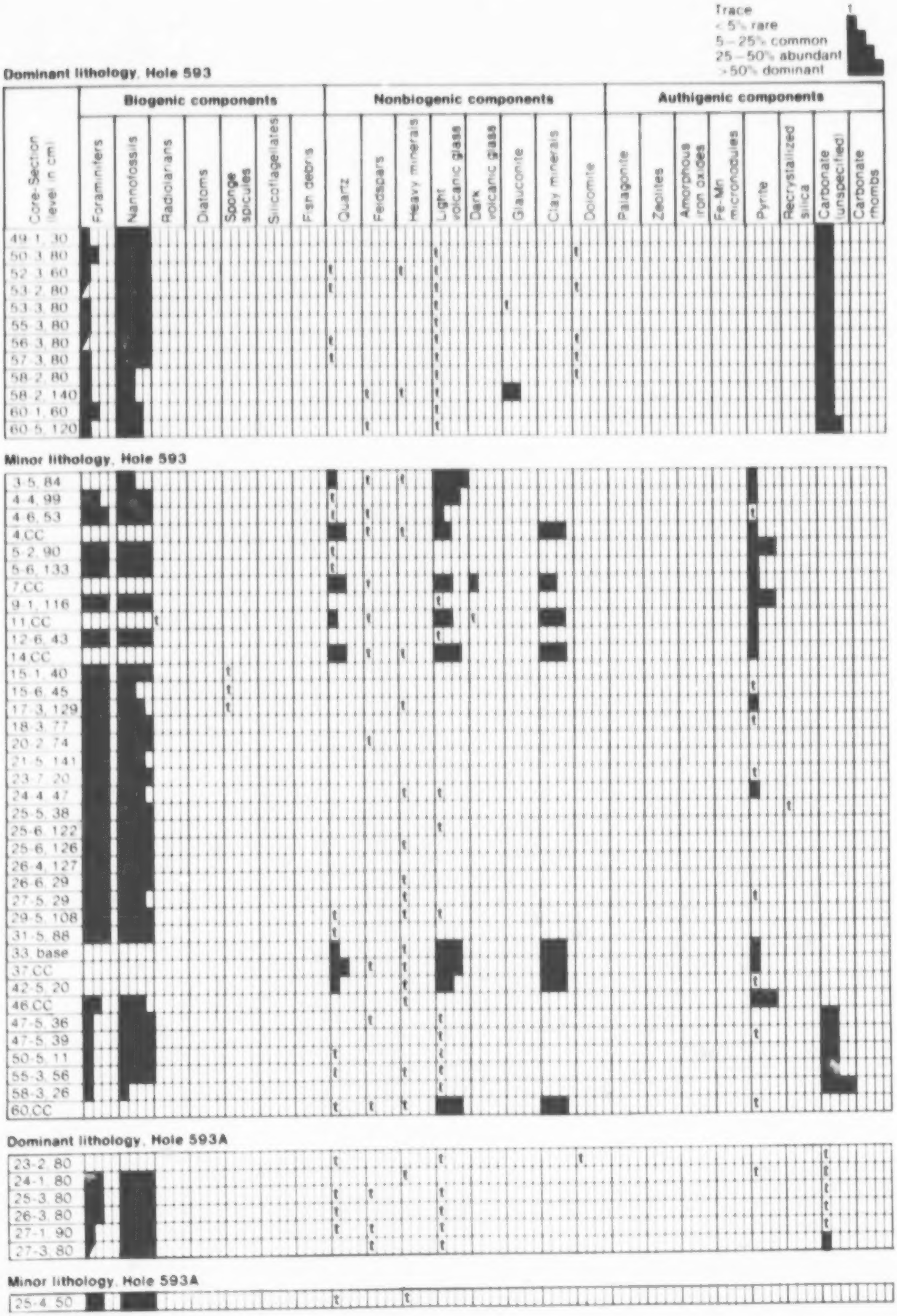


Figure 3. (Continued).

there occurs a zone that proved difficult to recover. The material recovered is composed of very homogeneous, firm, nannofossil ooze, indistinguishable from the sediment above and below. This zone occurs across the Miocene/Oligocene boundary, but the significance of the lack of recovery is unknown.

Unit II (593: 545.5–571.5 m; early late Eocene)

Unit II is composed of interbedded, lithified volcanogenic turbidites and light greenish gray (5GY 7/2) or white (N9) foraminifer-bearing nannofossil chalk to nannofossil chalk. The turbidites are grayish olive green (5GY 3/2) to dark gray (N4) and occur as a sequence of very fine- to coarse-grained packets. Some individual turbidites display good examples of Bouma A and B divisions (coarse massive, graded, to finely laminated) (Fig.) which generally dominate Bouma D and E divisions (very fine-grained).

The interbedded nannofossil chalk is identical in lithology to the overlying pelagic subunits but additionally has many thin (less than 2 mm thick), very pale green (10G 8/1) laminae that appear to be altered volcanic ash. The upper contact with Subunit ID is very sharp.

Discussion

The lithofacies at Site 593 is a thick sequence from the early late Eocene to Holocene that represents remarkably consistent pelagic conditions. Curiously there was no evidence of preserved siliceous biogenic material, even though the area had relatively high biogenic productivity—a situation similar to that at Sites 587 through 592. Insoluble residues of bulk sediment yield very small quantities of quartz grains, light-colored volcanic glass, clays, and pyrite(?). No evidence was found of ice-rafted debris at this mid-latitude site, which supports the conclusions of Kennett, Houtz, et al. (1975) that the site has been north of the iceberg limit since the late Miocene and extends this observation back to the late Eocene.

The color change that distinguishes Subunit IC from the surrounding subunits represents a change from post-depositional reduced conditions (Subunit ID) to oxidized conditions (Subunit IC) and back to a post-depositional reduced state (Subunit IB). The event that caused the oxidized state of Subunit IC must have altered the balance between available dissolved oxygen supplied to the seafloor and available organic carbon supplied to the in-

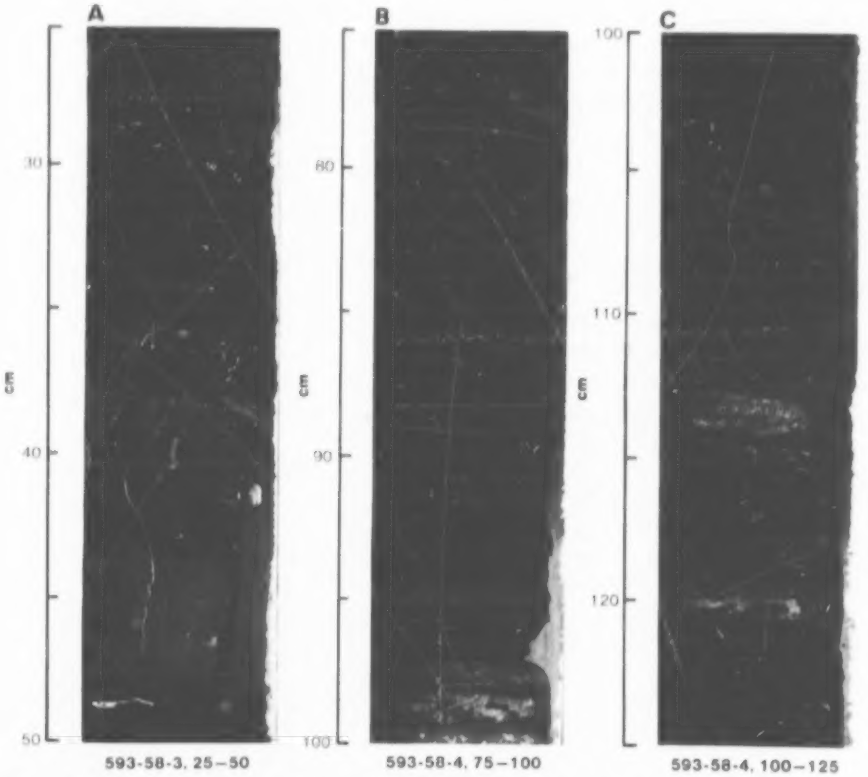


Figure 4. Examples of Bouma structures within lithostratigraphic Unit II, volcanogenic turbidites. A. Sharp basal contact at 48.5 cm with normally graded sequence beginning cross-bedded and laminated fine-grained, then at 28.5 cm the start of another packet. B. A coarse-grained, massive to bedded sequence, beginning at 95 cm, grading at 83 cm into fine-grained interbed, then at 75.5 cm another packet. C. A laminated, coarse-grained sequence at 115 cm, becoming massive and graded at 114 through 108.5 cm, then a rippled, fine-grained sequence through103.7 cm. Notice the erosional contact at 103.7 cm; coarse-grained silts have eroded into the finer-grained underlying material.

fauna and bacteria within the sediment. Compared to over- and underlying subunits, Subunit IC accumulated at a reduced sedimentation rate that allowed aerobic combustion of organic matter to greater burial depths. One possible explanation of this event would be the brief development or intensification of an oceanographic convergence not far to the south of Site 593 during this period. The effects of this convergence would have been relatively short-lived, because the sediment returns to a reduced state in Subunit IB. The surface oxidized zone (Subunit IA) may represent a similar phenomenon that reflects the flow of oxygen-charged Antarctic Intermediate Water from the Antarctic Convergence (Fig. 5).

The lithified volcanogenic turbidites and thin laminae of altered volcanic ash represents an episode of local volcanism in the late Eocene. The thin laminae of ash probably represents air-fall deposits and were regional precursors to the event or events that generated the turbidites. The internal structures of the individual flows, especially the dominant occurrence of Bouma A and B divisions compared to Bouma D and E divisions, suggest proximal rather than distal deposits (Walker, 1967). These observations imply that the source of the volcaniclastic material may have been nearby on the Challenger Plateau or, more likely, from "Lalitha Pinnacle," a buried volcanic "high" observed on the seismic profile to be near Site 593. The upper 115 m of the sequence is a foraminifer-bearing nannofossil ooze that probably represents an interval when bottom currents in this area were strong enough to winnow some nannofossils from the sediment, thereby increasing the relative abundance of foraminifers. The upper winnowed sequence at Site 593 is similar to the uppermost recovered sections at Sites 587 through 592 and probably coincides with a pe riod of more intensive global oceanic circulation.

PHYSICAL PROPERTIES

The HPC cores recovered from Hole 593 were sam pled for gravimetric evaluation using the standard cylin der technique on all of the cores except the final two, fo which chunk samples were taken (Boyce, 1976). Th GRAPE was employed on selected cores (see Introduc tion for details of experimental methods). Additional anal yses of the physical properties results for Site 593 are re ported by Morin (this volume).

The GRAPE saturated-bulk density results (points are plotted versus depth in Figure 6A. These data are di rectly converted to sediment porosity by assuming a grai density of 2.691 g/cm^3. The corresponding GRAPE po rosity results are presented versus depth in Figure 6B Mean values of density and porosity across each mete interval are calculated and these averages are plotted a the solid lines. After initially declining through the up per 50 m, porosity remains relatively constant over the next 300 m. This unusual behavior is reflected in the bulk density data. The sediment column shows little o no evidence of systematic, lithostatic compaction within the depth interval of 50 to 350 m. At 550 m, the porosity

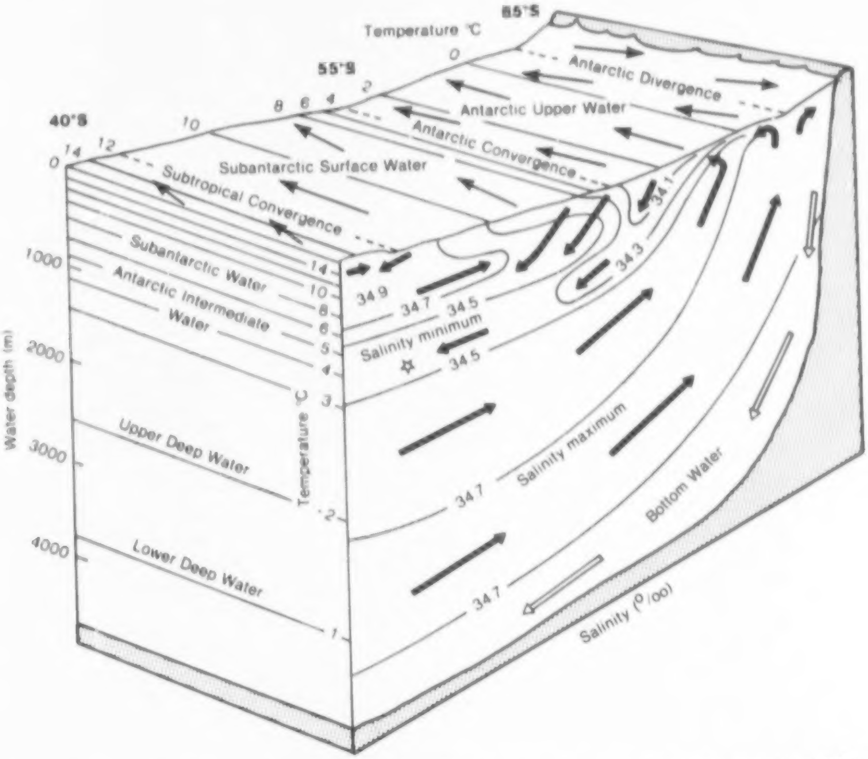

65°S
Temperature °C
55°S
40°S
0
2
4
6
8
10
12
14
Antarctic Divergence
Antarctic Upper Water
Antarctic Convergence
Subantarctic Surface Water
Subtropical Convergence
Subantarctic Water
Antarctic Intermediate Water
Upper Deep Water
Lower Deep Water
Water depth (m)
1000
2000
3000
4000
Temperature °C
14
10
8
6
5
4
3
2
1
34.9
34.7
34.5
34.1
34.3
Salinity minimum
Salinity maximum
Bottom Water
Salinity (0/00)

Figure 5. Schematic diagram of the vertical and horizontal structure of flow in the southern oceans (from Knox, 1970). Open star is approximate position of Site 593.

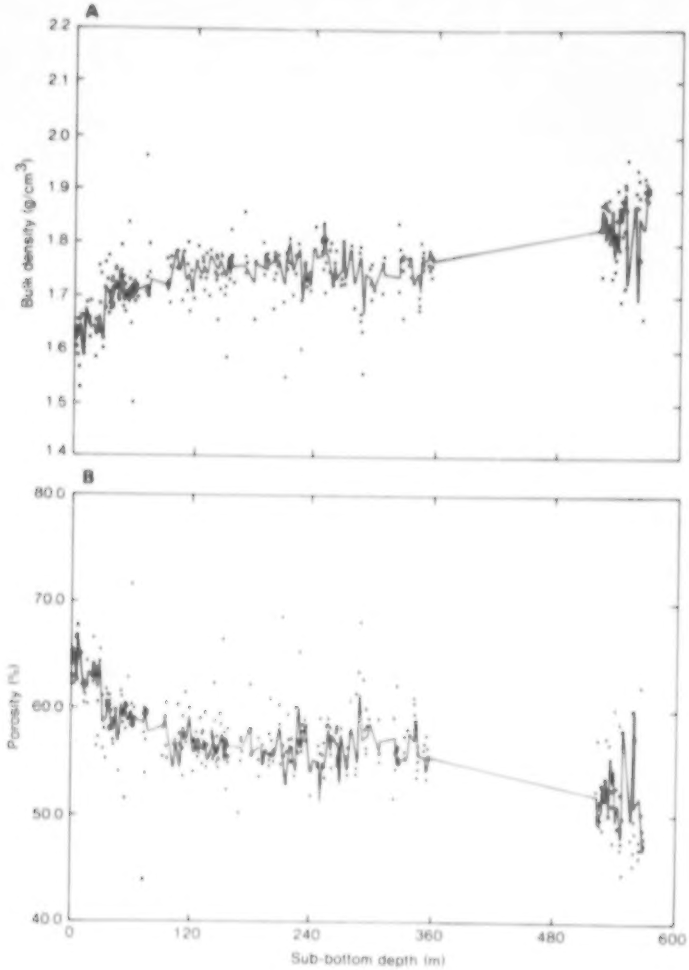


Figure 6. GRAPE wet-bulk density (A) and porosity (B) versus sub-bottom depth for Site 593.

finally decreases to less than 50% with the appearance of a layer of indurated volcanic material. Below this 15-m-thick zone, chalk appears with a slightly lower porosity.

A few chunk samples of the volcanic material was removed from Core 59 for preliminary evaluation. This material has a grain density of approximately 2.80 g/cm³. Sonic velocity data for these samples were determined and the results show values which are slightly higher (faster) than those found for calcareous sediments of equivalent porosity. For the Core 59 samples, few measurements were performed both parallel and perpendicular to bedding, with the latter producing slightly lower velocities:

Section (level in cm)	Sonic velocity (km/s)	Orientation
1, 70	2.546	Parallel to bedding
2, 70	2.340	Parallel
5, 70	2.155	Perpendicular

SEISMIC STRATIGRAPHY

Figure 7A is a portion of the shipboard water gun seismic profile collected during the approach to Site 593. Figure 7B is a line drawing of the profile, illustrating a possible unconformity at a sub-bottom depth of 0.54 s. Six acoustic units (A–F) have tentatively been identified, and these are compared in part with lithostratigraphic Units IA, IB, IC, ID, and II.

Acoustic Unit A comprises relatively low amplitude parallel reflectors, some of which are separated by acoustically transparent intervals. Acoustic Unit B is a zone of closely spaced parallel reflectors of moderate amplitude. Acoustic Unit C includes an interval of closely spaced parallel reflectors which lie directly below an apparent angular unconformity separating B and C. Alternatively, Units C and B may simply converge in the vicinity of Site 593, at the expense of a somewhat more transparent unit between B and C, which can be seen to lens out or be removed by erosion about 5 n. mi. north of Site 593 (Fig. 7B).

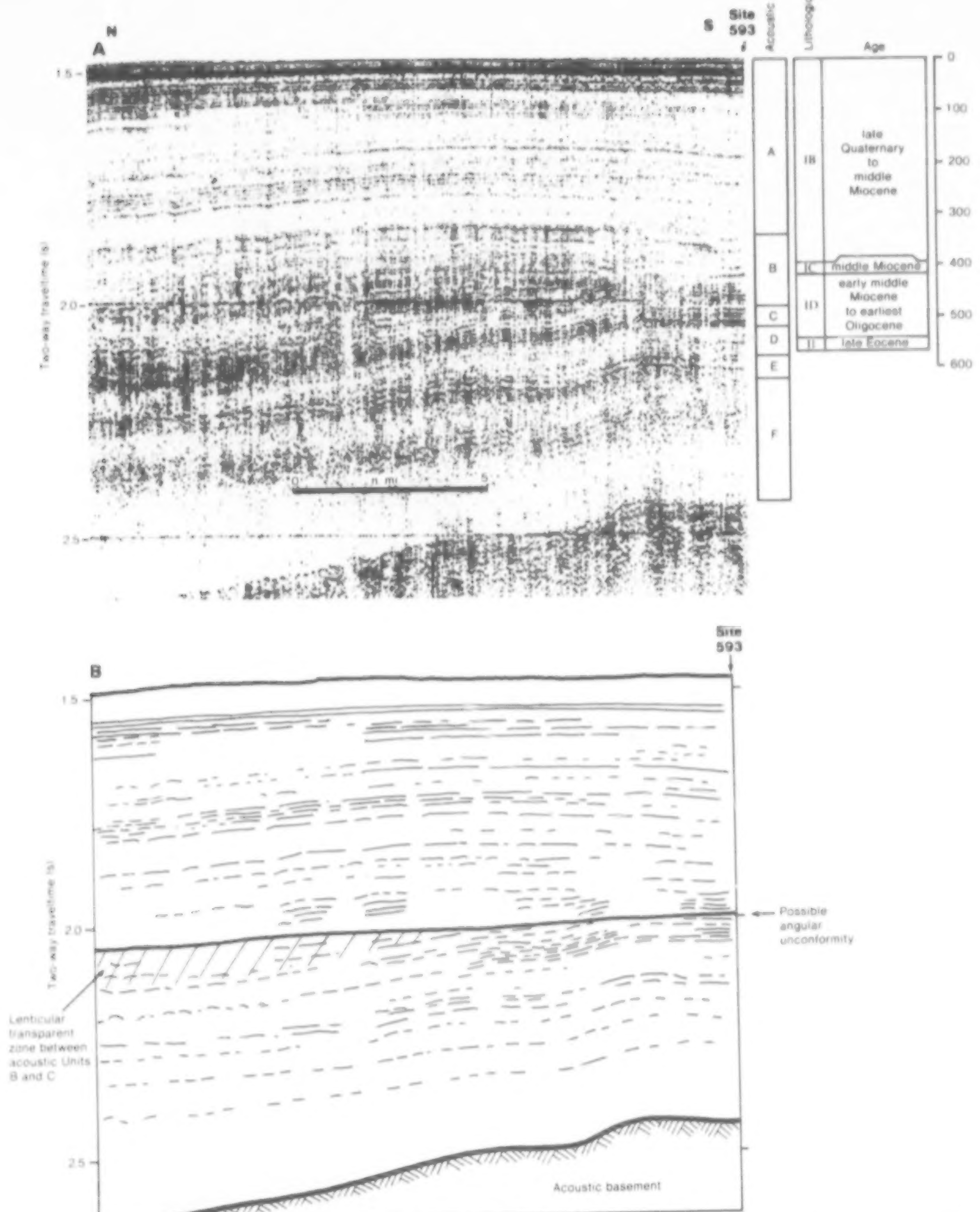


Figure 7. A. Comparison of acoustic Units A-F with lithological Units I and II. Shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1800 m/s. B. Line drawing of seismic profile shown in A; note possible angular unconformity and lenticular transparent zone.

Acoustic Unit D is a relatively transparent zone of uniform thickness. This overlies Unit E, an interval of strong, parallel reflectors which are subparallel to those of Unit C.

Acoustic Unit F is a transparent unit which includes an irregular zone of diffuse reflectors. Unit F overlies acoustic basement at a sub-bottom depth of 0.97 s.

Site 593 was drilled to a total depth of 571.5 m. Two lithostratigraphic units (Units I and II) are identified, with Unit I being subdivided into four subunits. Basic lithology of Unit I is a foraminifer-bearing nannofossil ooze. Unit II comprises a sequence of interbedded, lithified, volcanogenic turbidites and minor chalks which coincide with the Eocene/Oligocene boundary.

The lithologic units column shown in Figure 7A arbitrarily correlates the upper Eocene lithologic Unit II with acoustic Unit D. However, it is equally likely that Unit II may be correlated with the relatively strong reflector of acoustic Unit E, or the closely spaced reflectors of acoustic Unit C. Either of these may represent the seismic signature of the volcanogenic turbidites of lithologic Unit II.

BIOSTRATIGRAPHY

At Site 593 a complete sequence of Quaternary to late Eocene age was recovered. Hole 593A duplicated the Quaternary to late Miocene and the early Miocene to late Oligocene interval.

Calcareous nannoplankton and foraminifers are common throughout the drilled succession with the exception of the volcanic sequence in Cores 593-58 and 593-59, where both fossil groups were found only sporadically as contamination from above. Radiolarians, diatoms, and silicoflagellates have not been found at this site. Nannoplankton and foraminiferal zones are correlated in Figures 8 and 9.

The zonations of the calcareous nannoplankton and the planktonic foraminifers are hampered by the lack of certain index species. Discoasters and some ceratoliths are rare or absent from the early Pliocene; this is also true for *Catinaster* and some *Discoaster* species in the middle Miocene and for sphenoliths in the middle and late Oligocene.

A remarkable change in color from yellow brown below to white above was noted in Core 593-42, approximately at the top of nannoplankton Zones NN4/NN5, that is, just prior to the extinction of *Sphenolithus heteromorphus*. Calculation of the sedimentation rates indicates a sudden increase from 9.7 to 48.4 m/m.y. at this level.

The Oligocene/Miocene boundary was placed in Core 593-50, as indicated by the boundary between nannoplankton Zones NP25 and NN1 and the base of the foraminiferal *Globoquadrina dehiscens* Zone. The Eocene/Oligocene boundary probably falls in the interval containing volcanic material in Cores 593-58 and 593-59. The first calcareous layers above contain nannoplankton of the early Oligocene Zone NP21 and a foraminiferal fauna of the *Globigerina brevis* Zone. Samples from within the volcanic sequence contain only some species

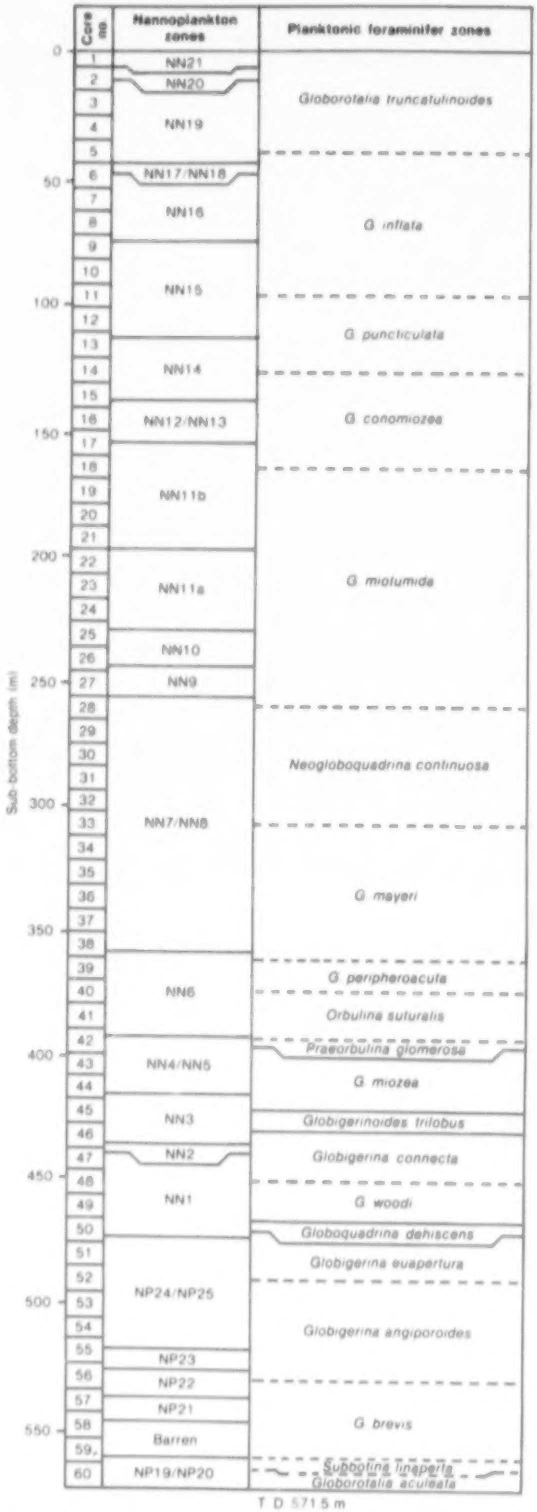


Figure 8. Correlation between calcareous nannoplankton and foraminiferal zones in Hole 593. Hole barren of radiolarians.

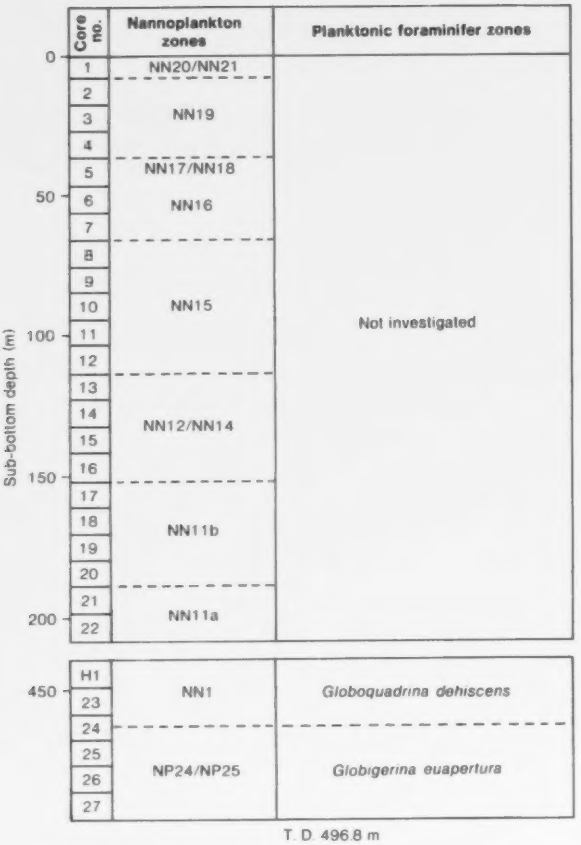


Figure 9. Correlation between calcareous nannoplankton and foraminiferal zones in Hole 593A. Hole barren of radiolarians.

without stratigraphic value and displaced nannoplankton and foraminifers from above, including Miocene and Quaternary species. Sample 593-59,CC could be placed in the late Eocene nannoplankton Zone NP19/NP20 and in the foraminiferal *Subbotina linaperta* Zone. Also reworked nannoplankton species like *Neococcolithus dubius* are present in samples from Core 60, probably in the same stratigraphic level as at Site 592. As the calculation of the sedimentation rate shows no obvious break at this level, a continuous sedimentation is assumed, and determining the absolute age of the volcanic material could provide useful data about the Eocene/Oligocene boundary.

As in Site 592, the Oligocene nannoplankton assemblages contain abundant *Zygrhablithus bijugatus*, indicating a shallow-water environment during this time interval. Data from the benthic foraminifers support this assumption.

Preservation of foraminifers and calcareous nannoplankton is good in the Quaternary and Pliocene, and for the foraminifers also in the Miocene and Oligocene. Preservation of the nannoplankton, however, is only moderate in the Miocene and is poor at certain levels through extensive calcite overgrowth, especially on discoasters and sphenoliths. In the Oligocene also, calcareous nannoplankton are commonly sturdy and exhibit considerable calcite overgrowths. In the late Eocene below the volcanic intercalation, preservation of the calcareous nannoplankton is moderate, but excellent foraminiferal preservation occurs in Sample 593-60,CC.

Planktonic Foraminifers

Zones

The following zones were identified at Site 593; t e zonal boundary markers are shown below:

Globorotalia truncatulinoides Zone
I. A. *G. truncatulinoides*
Globorotalia inflata Zone
I. A. *G. inflata*
Globorotalia puncticulata Zone
L. A. *G. conomiozea*
Globorotalia conomiozea Zone
I. A. *G. conomiozea*
Globorotalia miotumida Zone
L. A. *G. dehiscens*
Neogloboquadrina continuosa Zone
L. A. *G. mayeri*
Globorotalia mayeri Zone
L. A. *G. peripheroacuta*
Globorotalia peripheroacuta Zone
I. A. *G. peripheroacuta*
Orbulina suturalis Zone
I. A. *O. suturalis*
Praeorbulina glomerosa curva Zone
I. A. *P. glomerosa curva*
Globorotalia miozea Zone
I. A. *G. miozea*
Globigerinoides trilobus Zone
I. A. *G. trilobus*
Globigerina connecta Zone
I. A. *G. connecta*
Globigerina woodi Zone
I. A. *G. woodi*
Globoquadrina dehiscens Zone
I. A. *G. dehiscens*
Globigerina euapertura Zone
I. A. *G. angiporoides*
Globigerina angiporoides Zone
L. A. *G. brevis*
Globigerina brevis Zone
I. A. *G. brevis*
Subbotina linaperta Zone
L. A. *G. aculeata*
Globorotalia aculeata Zone

The *Globorotalia tosaensis* Zone and *G. truncatu inoides/G. tosaensis* Zones were not recognized at t is site because of the low numbers of *G. tosaensis.* Beca e of the low numbers of *N. continuosa* and its gradati n into *N. pachyderma* in the early late Miocene, it was cided to redefine the upper boundary of the *N. conti uosa* Zone at the extinction of *Globoquadrina dehisce s.* This event is regarded as a good marker in the temper e water mass of the southwest Pacific; further north in t e Pacific, *G. dehiscens* survived into the base of the N 8 Zone at Site 289 (Srinivasan and Kennett, 1981). The

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peripheroacuta Zone of middle Miocene age is recognized on the total range of the zone fossil.

Paleobiogeography

The planktonic foraminifers are abundant and well preserved from the Pleistocene through the Oligocene; faunas were less well preserved in the late Eocene but the lower core-catcher sample at the site produced an excellent fauna.

The late Eocene faunas show a progressive reduction in diversity toward the Eocene/Oligocene boundary; a lower diversity in the early Oligocene indicates cooler waters. Diversity increases toward the end of the Oligocene, which suggests a progressive warming, probably continuing through the early Miocene to the early part of the late Miocene in the lower *Globorotalia miotumida* Zone, where there is a marked change with the extinction of *Globigerinoides trilobus*. There probably was a warming in the late Miocene toward the top of the *Globorotalia miotumida* Zone to the base of the *G. conomiozea* Zone; this observation is based on the presence of *Globigerinella aequilateralis*. During the remaining late Miocene–early Pliocene, *G. aequilateralis* was not present in the area. For the remaining Pliocene to the Pleistocene, the surface water supported *G. aequilateralis* and the occasional *Globigerinoides ruber.*

Of importance at Site 593 is the presence of the short-ranging *Guembelitria samwelli* in the late Oligocene *Globigerina euapertura* Zone; its first appearance may have been a biogeographic response to the initiation of the Circum-Antarctic Current (Jenkins, 1974). Associated with *Guembelitria samwelli* is *Streptochilus pristinum,* and its presence here may also be associated with the initiation of the current.

Major Boundaries

Pliocene/Pleistocene: first appearance of *Globorotalia truncatulinoides*; because of the low numbers of *G. tosaensis*, it is not certain whether the first appearance of *G. truncatulinoides* is its first evolutionary appearance at this site.

Miocene/Pliocene: last appearance of *G. conomiozea.*

Oligocene/Miocene: the first appearance of *Globoquadrina dehiscens.*

Eocene/Oligocene: the extinction of *Globigerinatheka index.*

Benthic Foraminifers

Benthic foraminifers were examined from all core catchers at Site 593 in the fractions >63 μm. Benthics were very abundant in nearly all samples and their preservation remained good almost to the bottom of the hole; cementation was a slight problem in Cores 593-52 through 593-60. At many levels the benthics were fragmented. Dolomite occurs in Cores 593-23 and 593-53 to 593-55; the rhombs and crystals growing out of the foraminifers occur in Core 593-53.

Although the exact species composition of samples varied through the section, in general faunas contained large numbers of cibicidids and planulinids, with *Oridorsalis umbonatus, Bolivina* spp., and *Anomalinoides* spp. consistently present, but in smaller percentages. Uvigerinids become important at discrete intervals, but are consistently present only in the upper Eocene and upper Pliocene through Quaternary. Agglutinated genera are less abundant here than at other sites.

Along the Lord Howe Rise there is a north–south gradient in the abundances of several species. *Osangularia bengalensis, O. culter*, species of *Melonis, Rectuvigerina multistriata, Gyroidinoides nitidula, Uvigerina gemmaeformis, Anomalinoides globulosa*, and numerous other forms are less common in Site 593. Species more common at Site 593 than in sites to the north include not only the New Zealand endemic forms such as *Hopkinsina mioindex, Rotaliatina sulcigera,* and *Cibicidoides molestus,* but also *Bulimina aculeata, Uvigerina* aff. *mediterranea, Vulvulina haeringensis, Planulina marialana gigas,* and *P. harangensis.*

Eocene faunas (Cores 60–57) are generally similar to those at Site 592; there is a smaller proportion of large, ornamented cibicidids such as *C. molestus* and *Cibicides tholus* at Site 593, but a larger proportion of *Globocassidulina subglobosa* and *Uvigerina bortotara* and *U. rippensis-havanensis*. The distinctive species of *Vaginulinopsis* present at Site 592 were not found here.

Changes across the Eocene/Oligocene boundary (Cores 593-57 to 593-55) include the disappearance of *U. rippensis,* the first appearance of *Sphaeroidina bulloides,* and a change in dominance from cibicidids, particularly the larger ornamented types, to *Globocassidulina subglobosa,* which remains dominant through most of the Oligocene. In the basal Oligocene the striate bolivinids, *Martinottiella occidentalis* and *Cassidulina crassa,* first appear, and the hispido-costate uvigerinids are replaced by *Rectuvigerina multistriata* and, in Cores 593-53 to 593-52, the typical North Atlantic species *U. semivestita*. The first appearances of all these species agree with their proposed evolution in other parts of the world ocean.

Between Cores 593-50 and 593-52 (upper Oligocene, *Globigerina angiporoides/G. euapertura* Zones) the Circum-Antarctica Current is postulated to have developed. There is much breakage of the fossils in these two cores. Diversity of the benthics decreases (possibly because preservation was poorer) and several new species first occur at this site, including the important Neogene species *Heterolepa kullenbergi* and *U. pygmaea.*

Several of the typically Paleogene benthic species disappear during the early Miocene (Cores 593-49 to 593-40) at this site, including *Cibicidoides tuxpamensis, C. io,* and *Bulimina macilenta.* Lower Miocene faunas demonstrate little change in diversity, but contain distinctly fewer individuals than those of other times. The consistent presence of *Robulus* spp. through this interval is important, since it allows correlation with the dissolved faunas through this interval at Site 592. At both sites, then, the low numbers of benthics reflect some property of the environment, not just dissolution effects.

In the lowermost middle Miocene (Cores 593-43 to 593-42, *Praeorbulina glomerosa curva–Globorotalia miozea* Zones), there is a yellow, oxidized layer through the sediments. In this interval the character of the benthic fauna remains surprisingly constant. A few forms appear, including *Melonis barleeanum, Bolivina anastomosa,* and *Uvigerina auberiana*. However, the small, hispid uvigerinids occur in large numbers in Sample 593-42,CC and may be a reflection of the suggested oxidation of these levels. Such uvigerinids are typical of the shallowest and deepest parts of the oceanic water column, which are generally oxygen-rich.

The large change during the lower Miocene occurs in the *P. glomerosa curva* to *Orbulina suturalis* Zones. Both the diversity and abundance of benthics increase. The rectuvigerinids disappear temporarily and seven new entrants appear, at least four of which are cibicidids. *Nuttalides umbonifera*, a form correlated with deep water masses later in the Neogene, first occurs at this site.

The new, typically Pliocene–Quaternary benthic species first evolve in the mid-Miocene *Globorotalia* Zone (Cores 593-38 to 593-34). Such species as *Cassidulina carinata, Cibicidoides mundulus, C. cicatricosus,* and *Rectuvigerina spinea* first appear at this time, but disappear by the *Neogloboquadrina continuosa* Zone, only to reappear in the Pliocene.

The first pulse of miliolids, accompanied by the deep-water index, *Pullenia quinqueloba,* appears in the *G. miotumida* Zone (Cores 28 to 27). The only consistent occurrences of the more northerly species *Osangularia bengalensis* and less common *O. culter* occur throughout most of this zone.

Uvigerinids again appear at the top of the *G. conomiozea* Zone, as at other sites on this leg; however, at this site the species which mark the top of the Miocene are *Uvigerina auberiana* and *U. pygmaea,* both tiny species more typical of deeper waters and sites.

A larger change in benthic faunas and in the uvigerinids occurs, however, in the basal Pliocene (Cores 593-11 and 593-12). Benthic diversity drops, there is an influx of miliolids, and particularly of large, abraded spiroloculinids which may be redeposited from shallower water. *U. hispido-costata* occurs for the first time and continues to occur at this site through the course of the Pliocene and Quaternary.

The faunal changes associated with the development of Northern Hemisphere glaciation inferred between Cores 593-11 and 593-9 (*Globorotalia puncticulata/G. inflata* Zones) are less prominent than the changes that occur in the early Pliocene. Diversity drops, several species disappear, *Globocassidulina* increases in abundance, and *N. umbonifera* again appears in the faunas, albeit in small numbers.

Within the *Globorotalia inflata* Zone (Cores 593-7 to 593-4) miliolids become more important, *Bulimina aculeata* first occurs and becomes a prominent part of the faunas, and the deeper-water index, *P. quinqueloba,* occurs through most of the zone. Beginning in this zone there is a trend to lower diversity and higher dominance of the fewer species. This trend is accentuated in the Quaternary, when only a few species, including *Cassidulina carinata* and *B. aculeata*, are very abundant. *Epistominella exigua* appears in the Pleistocene (Sample 593-2,CC) at this site.

Calcareous Nannoplankton

Core-catcher samples and enough additional samples accurately to determine zonal boundaries were examined for calcareous nannoplankton. Some of the zonal indicators are absent at Site 593. Middle and late Oligocene zone-defining sphenoliths were not observed, and Zones NP24/NP25 could not be differentiated. The first occurrence of *Discoaster exilis* is used to define the top of the *Helicosphaera ampliaperta* Zone (NN4) instead of the last occurrence of *Helicosphaera ampliaperta*. The top of the *D. asymmetricus* Zone (NN14) is defined on the last occurrence of *Amaurolithus primus* instead of *A. tricorniculatus* in Hole 593. (*A. tricorniculatus* was observed at this level in Hole 593A.) The last occurrence of *D. neohamatus* is used instead of the first occurrence of *D. quinqueramus* to approximate the top of the *D. calcaris* Zone (NN10). *Catinaster coalitus* and *D. kugleri* were not observed at this site.

Calcareous nannoplankton are abundant throughout the section at Site 593. Most species are well preserved but most discoasters become progressively more overgrown with depth. Many early and middle Miocene sphenoliths are also overgrown.

Hole 593

Quaternary

Samples 593-1,CC and 593-2-3, 3–4 cm are above the last occurrence of *Pseudoemiliania lacunosa* and belong in the late Quaternary *Gephyrocapsa oceanica* Zone or *Emiliania huxleyi* Zone (NN20/NN21).

The upper part of the early Pleistocene *Pseudoemiliania lacunosa* Zone (NN19b) includes Samples 593-2-5, 3–4 cm to 593-3-1, 3–4 cm. The last occurrence of *Calcidiscus macintyrei* in Sample 593-3-3, 3–4 cm places this Sample 593-5,CC in the lower part of the *P. lacunosa* Zone (NN19a).

Pliocene

The last occurrence of *Discoaster brouweri* in Sample 593-6-1, 3–4 cm places this sample in the late Pliocene *Discoaster brouweri* Zone (NN18). The addition of *D. pentaradiatus* in Sample 593-6-2, 3–4 cm places this sample in the *D. pentaradiatus* Zone (NN17). The late Pliocene *D. surculus* Zone (NN16) includes Samples 593-6-3, 3–4 cm to 593-9-1, 3–4 cm, above the last occurrence of *Reticulofenestra pseudoumbilica* Zone (NN15) includes Samples 593-9-3, 3–4 cm. The early Pliocene *Reticulofenestra pseudoumbilica* in Sample 593-9-3, 3–4 cm to 593-13-1, 3–4 cm. *Amaurolithus tricorniculatus* was not observed in Hole 593. Instead, the last occurrence of *A. primus* in Sample 593-13-3, 3–4 cm is used to mark the top of the early Pliocene *Discoaster asymmetricus* Zone (NN14), which includes this sample to Sample 593-15-5, 3–4 cm. Samples 593-15,CC and 593-16,CC are placed in the combined *A. tricorniculatus/Ceratolithus rugosus* Zone (NN12/13). The boundary between these zones is defined by the first occurrence of *Ceratolithus rugosus*, which was not observed at this site.

Miocene

The last occurrence of *D. quinqueramus* in Sample 593-17-5, 3–4 cm and first occurrence of *A. primus* in Sample 593-22,CC places this interval in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). In the absence of *D. quinqueramus* below this level, the base of the lower subzone (NN11a) is placed between Samples 593-25-1, 3–4 cm and 593-25-3, 3–4 cm, the last occurrence of *D. neohamatus*, which approximates the first occurrence of *D. quinqueramus*. Samples 593-25-3, 3–4 cm to 593-26-5, 3–4 cm, above the last occurrence of *D. hamatus* in Sample 593-26,CC, are placed in the middle Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus* from Samples 593-26,CC to 593-27,CC places these samples in the middle Miocene *D. hamatus* Zone (NN9).

Catinaster coalitus and *D. kugleri* were not observed at this site; therefore, boundaries between the middle Miocene Zones NN8, NN7, and NN6 cannot be determined. This unzoned interval includes Samples 593-28-1, 3–4 cm to 593-42-4, 99–100 cm. The last occurrence of *Sphenolithus heteromorphus* in Sample 593-42-5, 3–4 cm marks the top of the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). In the absence of *Helicosphaera ampliaperta* at this site, the first occurrence of *D. exilis* in Sample 593-43,CC is used for the base of Zone NN5. Samples 593-44-1, 3–4 cm and 593-44-5, 3–4 cm, above the last occurrence of *S. belemnos* in Sample 593-44,CC, are placed in the early Miocene *Helicosphaera ampliaperta* Zone (NN4). The last occurrence of *Triquetrorhabdulus carinatus* is in Sample 593-46,CC. Therefore Samples 593-44,CC to 593-46-5, 3–4 cm are placed in the early Miocene *Sphenolithus belemnos* Zone (NN3). One sample, 593-46,CC, contains both *T. carinatus* and *D. druggi*, which places it in the early Miocene *D. druggii* Zone (NN2). Samples 593-47-1, 3–4 cm to 593-50-5, 3–4 cm, below the first occurrence of *D. druggii*, are placed in the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1).

Oligocene

The last occurrence of *Zygrhablithus bijugatus* in Sample 593-5, 3–4 cm marks the top of the Oligocene. The last occurrence of *R. umbilica* in Samples 593-56-3, 3–4 cm to 593-57-5, 3–4 cm, above the last occurrence of *Cyclococcolithus formosus* in Sample 593-57-3, 3–4 cm, places these samples in the early Oligocene *H. reticulata* Zone (NP22). The early Oligocene *Ericsonia? subdisticha* Zone (NP21) extends down at least to Sample 593-58-2, 110–111 cm. The base of Zone NP21, the Oligocene/Eocene boundary, is within an interval from Samples 593-58-3, 13 cm to 593-59-4, 71–72 cm.

Eocene

The occurrence of *D. saipanensis* and *Cribrocentrum reticulatum* below or in Sample 593-59,CC and the occurrence of *Isthmolithus recurvus* down to Sample 593-60,CC places this interval in the late Eocene Zone NP19/NP20. From Sample 593-60-1, 6–7 cm downward reworked nannoplankton species from the late middle and early late Eocene, like *Neococcolithus dubius* and *Chiasmolithus solitus*, were noted.

Hole 593A

Core-catcher samples were examined through Core 22 with no significant differences between Holes 593 and 593A. The hole was washed down to 448.8 m sub-bottom. Samples 593A-23,CC to 593A-24-1, 3–4 cm are placed in the early Miocene *T. carinatus* Zone (NN1) by the presence of *T. carinatus* and the absence of *D. druggii.*

The occurrence of *Z. bijugatus* and *H. recta* in Sample 593A-24,CC places this sample in the late Oligocene *S. ciperoensis* Zone (NP25). The Oligocene/Miocene boundary is between Samples 593A-24-1, 3–4 cm and 593A-24,CC. Three additional cores were drilled below Core 24 and are of late Oligocene age.

Radiolarians, Diatoms, and Silicoflagellates

Radiolarians, diatoms, and silicoflagellates were not observed in the late Eocene to Recent sequence at this site.

PALEOMAGNETISM

The magnetic properties of sediments from Site 593 were generally similar to those from Site 592 except for an extended zone of high intensity from 360 to 455 m sub-bottom depth encompassing Subunit IC. Intensities were slightly higher than at Site 592. A polarity stratigraphy was obtained back to 3.3 m.y. ago.

Hole 593 was generally subsampled at three specimens per section and the first 11 cores from Hole 593A were subsampled at two or sometimes three specimens per section. The Kuster orientation tool has a success rate of 64% in Hole 593, with good agreement between drift (i.e., tilt) azimuths. Four cores from Hole 593A were oriented. Laboratory measurements for NRM have been completed on most specimens from Hole 593, and low-field susceptibility measurements have been made on Cores 593-1 to 593-24. Shipboard NRM measurements were made on the volcanogenic turbidite zone in Hole 593. The few shipboard measurements made on Hole 593A were consistent with results from Hole 593. NRM statistics for Hole 593, excluding the volcanogenic turbidite zone, are as follows:

Geometric mean intensity (μG) =	0.110
Scalar mean inclination (± 1 s.d.) =	+3.9 ±41.7°
Axial dipole inclination =	−59.7°
Mean angle between repeats =	20.3° (55 repeats)

Low-field susceptibilities were marginally higher than for the corresponding units at Site 592:

Zone (Core-Section, level in cm)	Susceptibility
1-1, 10 to 1-1, 125	Weak positive
1-2, 10 to 6-3, 25	Diamagnetic
6-4, 25 to 14-4, 125	Weak positive (~ 1-3 μG/Oe)
14-5, 25 to 17-2, 25	Very weak positive (< 1 μG/Oe)
14-7, 75 to 26-1, 75	Diamagnetic

The comment made in the Site 592 paleomagnetic report concerning the significance of diamagnetic (negative) susceptibilities is equally applicable here.

The magnetization of these carbonate oozes is extremely weak. Intensities fall from about 15 to about 0.4 μG in the uppermost half meter of pale brown oxidized sediment, thence to characteristically low values below the bottom of Core 593-1. The surficial high-intensity layer was absent from the top of Hole 593A. A region of uniformly high intensity (1.5 to 4 μG) spans Cores 593-41 through 593-46, preceded by a gradual increase starting at the bottom of Core 593-50 and terminating with a steady decline in Cores 593-40 and 593-39. The range of this zone is somewhat wider than that of the pale orange to yellow gray Subunit IC. It appears to correlate with similar zones at Sites 588 and 592 and marks a change in the sedimentological regime over a wide area during the early and middle Miocene. Stein and Sarnthein (this volume) propose that during this period Australia would have been at higher latitudes and exposed to strong westerly winds, resulting in an increase in eolian terrigenous material in sediments on the Lord Howe Rise. This would account for the high-intensity zone, but is not a convincing explanation of the fairly abrupt termination of the zone.

A magnetic polarity stratigraphy can be traced downward as far as the middle of the Gauss Chron at about 3.3 m.y. (Fig. 10). Deformation caused by coring was fairly common in the first eight cores from Hole 593. Despite this the Brunhes/Matuyama boundary and the Jaramillo Subchron appear to be well resolved. It was not possible to identify the Olduvai Subchron, and the lower part of the stratigraphy given in the figure is somewhat speculative. At greater depths, with the exception of the volcanogenic Unit II, directions are too scattered for a polarity interpretation to be made based on the NRM data.

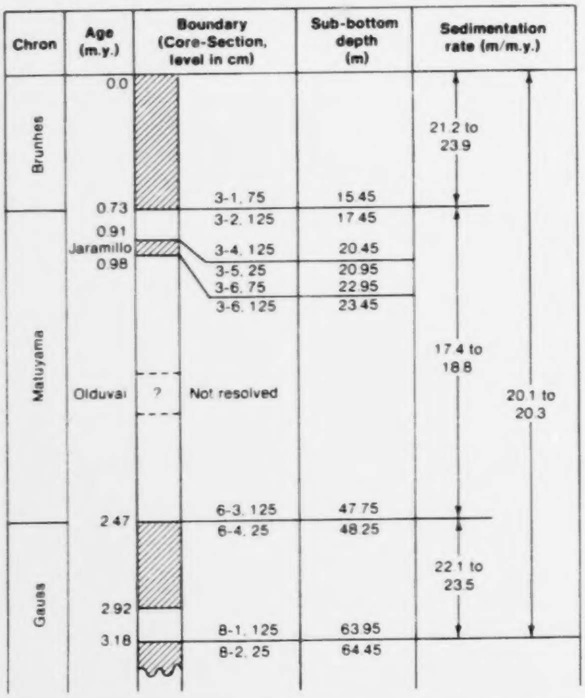


Figure 10. Magnetic polarity stratigraphy for the upper part of Hole 593.

It was surprising to find predominantly reversed (positive) inclinations for Cores 593-34 through 593-46. Much of this interval comprises the early and early middle Miocene high-intensity region in which directional data are highly reproducible. Furthermore, declinations in the high-intensity region were found to fall nearly always into the same quadrant for successive cores with positive inclinations, despite the fact that the azimuthal orientation of successive cores is expected to be random. It must be concluded therefore that the sediments in this region have acquired a large secondary remanence, either during or after coring. Partial AF demagnetization tests on this hole have yet to be performed.

Shipboard NRM measurements on the volcanogenic turbidite Unit II indicated reversed polarity throughout and magnetizations much less than would be expected for fresh volcanic material (Table 3). Lower intensities tended to be associated with the more fine-grained samples, which points to a greater degree of alteration in the fine-grained material.

SEDIMENTATION RATES

Sedimentation rates are calculated as outlined for the previous sites, but intervals used are subdivided if necessary or slightly changed according to datum levels available, especially in the early Miocene and middle to late Oligocene (Fig. 11). A few nannoplankton zones had to be combined, because some index species are missing at this southern high latitude.

In the late Eocene and Oligocene interval (nannoplankton Zones NP19/NP20 top to NP25 top) the sedimentation rate is only 4.6 m/m.y. (including the volcanic material in Cores 58 and 59). In the early to early middle Miocene (Zones NP25 top to NN5 top) the sedimentation rate is 9.7 m/m.y., based on five datum levels. At the top of nannoplankton Zone NN5 the sedimentation rate increases very suddenly to 48.4 m/m.y. in the middle Miocene (Zones NN5 top to NN8 top), at a level which is marked by change of color from yellow brown to white in the calcareous sediments (Core 593-42). In the late Miocene and early Pliocene (nannoplankton

Table 3. NRM data for the volcanogenic turbidite Unit II.

Core-Section (level in cm)	Intensity (μG)	Polarity[a]	Inclination	Comments
58-3, 30-32	6.94	R	15	Bedded, fine-grained, black
58-3, 72-74	14.91	R	50	Uniform, med.-grained, green/g
59-1, 94-96	111.62	R	53	Bedded, fine/med., green/black
59-2, 132-134	~220.00	R	Pos.	Mottled, med./coarse, green/gra
59-3, 50-52	77.76	R	70	Bedded horiz., med., green/gray
59-3, 132-134	20.31	R	49	Fine, black/green
59-4, 128-130	0.32	R?	25	V. fine, black
59-5, 65-67	0.67	N?	−22	Reproducible med., green/gray
59-5, 100-102	1.61	R	9	Fine, half gray, half black laminated
59,CC 10-12	0.35	R?	Pos.	Med., gray (with CO_3)
60-2, 75-77	0.39	R?	−45	Burrowed, fine, pale gray

Note: Queries denote specimens too weak to be measured reliably.

[a] R = reversed, N = normal.

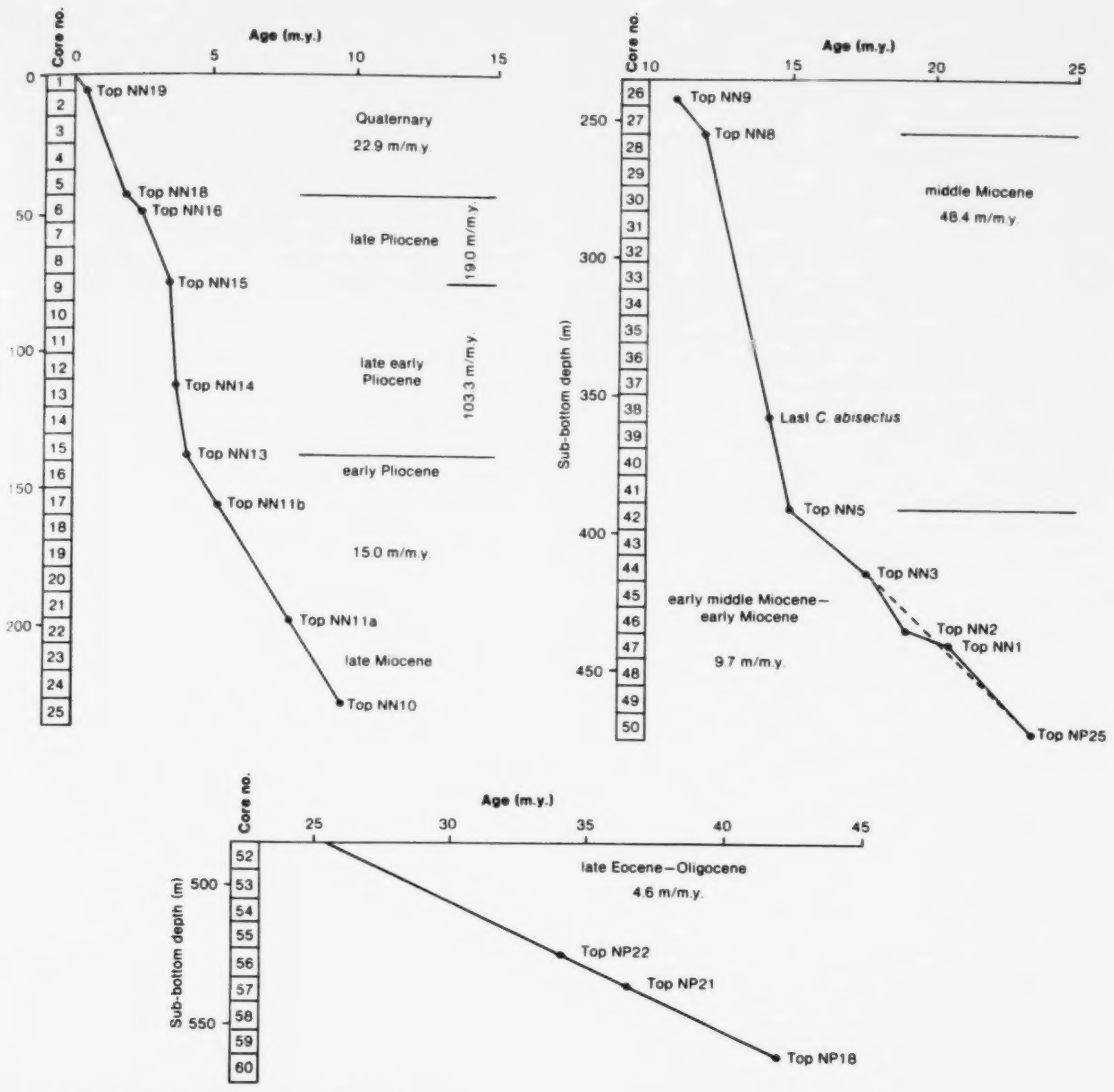


Figure 11. Sedimentation rates and datum levels in Hole 593.

Zones NN8 top to NN13 top) the sedimentation rate drops to 15.0 m/m.y., based on five datum levels.

As was true for previous sites, the sedimentation rate increases in the late early Pliocene (nannoplankton Zones NN14 and NN15), and is 103.3 m/m.y. In the late Pliocene (Zones NN16 to NN18) it drops again to 19.0 m/m.y., based on three datum levels. In the Quaternary (above nannoplankton Zone NN18 top), it increases slightly to 22.9 m/m.y., which is more than twice the amount of that at Site 592.

SUMMARY AND CONCLUSIONS

Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau, in a relatively shallow water depth of 1068 m at a position 40°30.47′S, 167°40.47′E. The Challenger Plateau is effectively a topographic extension of Lord Howe Rise and its western part provides a shallow-water pedestal 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed accumulation of an uncomplicated Paleogene to Neogene pelagic ooze sequence with virtually no terrigenous sedimentary influences. Site 593 is a reoccupation of Site 284, which was cored during Leg 29 of the Deep Sea Drilling Project.

Site 593 consists of two holes continuously cored to a maximum sub-bottom depth of 571.5 m. Hole 593 was cored with the HPC from 0 to 254.1 m sub-bottom and continued to a total depth of 571.5 m with the XCB. Hole 593A was continuously cored with the HPC from 0 to 209.3 m sub-bottom, then washed down to 448.8 m and cored with the XCB to 496.8 m to recover the Oligocene/Miocene transition. This interval was poorly cored in the first hole.

Site 593 is an apparently continuous stratigraphic sequence from the late Eocene (42 m.y. ago) to the Quaternary (Fig. 12). The general facies is a rather monotonous foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze and a nannofossil chalk with depth. The transition to reduced abundances of foraminifers, from about 15 to about 5%, occurs at about 110 m. The sediment is predominantly calcareous nannofossils with subordinate foraminifers. Other components, such as quartz and feldspar grains, volcanic glass, and pyrite(?), occur only in trace (< 1%) abundances (Fig. 3). Micritic carbonate occurs in persistent abundances of 5 to 10% from 323 m to total depth, but the sediment does not become chalk until 562 m. The only biogenic silica found comprised traces (< 1%) of sponge spicules in a zone from about 249 to 296 m.

The sequence at Site 593 has been divided into two units. Unit I has been subdivided into four subunits (Fig. 12):

Subunit IA, of late Quaternary age, is a yellow gray foraminifer-bearing nannofossil ooze and represents an upper oxidized layer, correlating with a similar subunit at most other sites. The relatively high content of foraminifers appears to be the result of winnowing.

Subunit IB, of late Quaternary to middle Miocene age, is a light gray foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze with depth. It is distinguished by its much lighter color compared with overlying Subunit IA and underlying Subunit IC.

Subunit IC, of middle Miocene age, is distinguished from two overlying and underlying subunits by its distinctive pale orange color, but is otherwise homogeneous and identical in lithology to the surrounding subunits.

Subunit ID, of early middle Miocene to earliest Oligocene age, is a white nannofossil ooze that is identical in lithology to the lower part of Subunit IB. Subunit ID is defined by its stratigraphic position below the easily recognized pale orange Subunit IC.

Between about 475 and 485 m in Hole 593 and about 455 and 468 m in Hole 593A, there occurs a zone that was difficult to recover. It comprises very homogeneous, firm, nannofossil ooze, indistinguishable from the sediment above and below. This zone occurs across the Miocene/Oligocene boundary. The reason for lack of recovery is unknown.

Unit II, of late earliest Oligocene to early late Eocene age, is composed of interbedded, lithified volcanogenic turbidites and pyroclastic flows and light greenish gray or white foraminifer-bearing nannofossil chalk to nannofossil chalk. The turbidites are grayish olive green to dark gray and occur as a sequence of very fine- to coarse-grained packets.

The interbedded nannofossil chalk is identical in lithology to the overlying pelagic subunits but additionally contains many thin (< 2 mm thick), very pale green laminae that appear to be altered volcanic ash. The upper contact with Subunit ID is very sharp.

Site 593 offers a very fine, complete biostratigraphic succession in southern temperate latitudes. A paleomagnetic polarity stratigraphy has been identified back to the middle of the Gauss Chron (3.2 m.y. ago). Calcareous nannoplankton and foraminifers are common throughout except in the volcanic sequence, where both fossil groups were found sporadically only as contamination from above. Radiolarians, diatoms, and silicoflagellates have not been found at this site. Correlations between nannoplankton and foraminiferal zones are shown in Figure 1 .

Preservation of foraminifers is of high quality through the entire section except for the Eocene. Calcareous nannofossils are well preserved in the Quaternary and Pliocene, but only moderately so in the Miocene and poorly so at certain levels because of the extensive calcite overgrowth, especially on discoasters and sphenoliths. In the Oligocene, calcareous nannoplankton are commonly stubby and also exhibit considerable calcite overgrowths. In the late Eocene below the volcanic intercalation, preservation is improved for the calcareous nannoplankton; Core 60 contains well-preserved nannoplankton and excellently preserved foraminifers.

The zonation of planktonic foraminifers is typically that of the temperate regions. However, the zonation of the calcareous nannofossils is much more generalized than is true at lower latitudes. Warm-water calcareous nannofossils become much less common at this site. A number of mid- to low-latitude zones cannot be recognized because certain index species are missing. Discoasters and some ceratoliths are rare or absent from the early Pliocene. In the middle Miocene, *Catinaster* and some discoasters are rare or absent, which is also true for sphenoliths in the middle and late Oligocene.

All of the epoch boundaries are well represented at Site 593, from the Eocene/Oligocene to the Pliocene/Pleistocene. Of particular interest at this site are the Oligocene/Miocene and the Eocene/Oligocene boundaries. The Oligocene/Miocene boundary was encountered in Core 593-59, as indicated by the boundary between nannoplankton Zones NP25 and NN1 and the base of the foraminiferal *Globoquadrina dehiscens* Zone. This boundary coincides with a much firmer nannofossil ooze/chalk zone that is otherwise homogeneous with the surrounding sediments. The significance of this layer is as yet unknown. The Eocene/Oligocene boundary falls in the interval containing volcanic material in Cores 593-58 and 593-59. The first calcareous layers above contain nannoplankton of the early Oligocene Zone NP21 and a foraminiferal fauna of the *Globigerina brevis* Zone. Samples from within the volcanic sequence contain only some species without stratigraphic value and displaced nannoplankton and foraminifers from above, including Miocene species. Sample 593-59,CC could be placed in the late Eocene nannoplankton Zone NP19/NP20 and in the foraminiferal *Subbotina linaperta* Zone. As the calculation of the sedimentation rate shows no obvious break at this level, a continuous sedimentation rate is assumed,

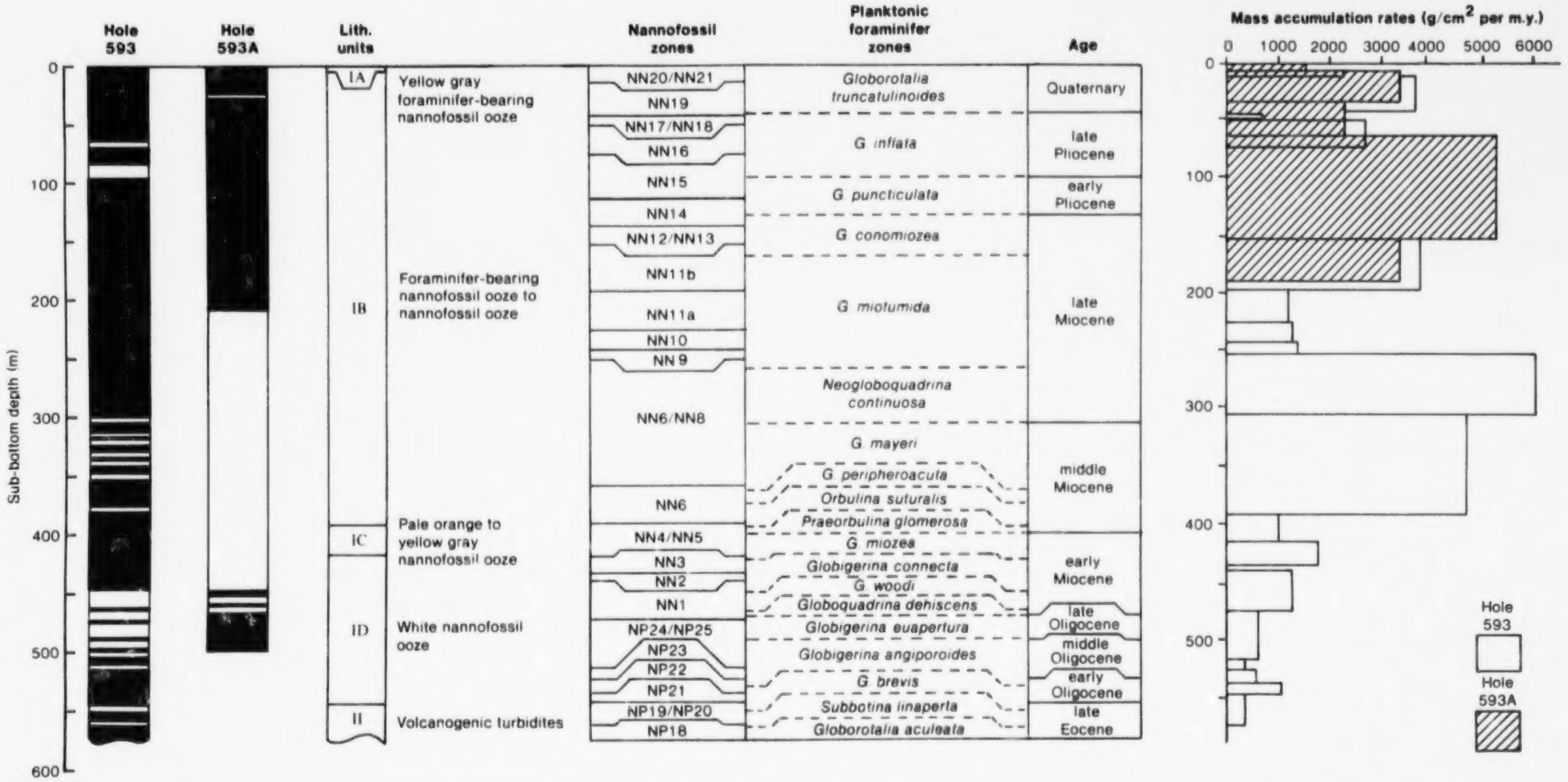


Figure 12. Summary lithology, biostratigraphy, and mass accumulation rates of Site 593 (recovery in black).

and the determination of a radiometric age for the volcanic material should assist with the dating of the Eocene/Oligocene boundary.

Paleoenvironmental History of Site 593

In general, the monotonous sedimentary sequence at Site 593 indicates a very consistent environment of deposition during the last 42 m.y., punctuated only by two major events at 38 m.y. ago and 15.5 to 15 m.y. ago and a minor event at 23.5 m.y. ago. The calcareous oozes were deposited in an oceanic environment at middle bathyal depths on the Challenger Plateau, with little evidence that the depth of the ocean floor changed. There was virtually no terrigenous input except for minor volcanic ash layers.

Nannofossil ooze (now chalk) was deposited during the late Eocene. The presence of many altered volcanic ash layers indicate that this was an active period of explosive volcanicity (42 to 38 m.y. ago).

This largely biogenic sedimentation was suddenly interrupted at the end of the Eocene (about 38 m.y. ago) by the deposition at the Eocene/Oligocene boundary of a 15-m layer of volcanogenic proximal turbidites, debris flows, and pyroclastic flows. These were deposited, probably rapidly, as a result of submarine volcanism at middle(?) bathyal depths, probably from "Lalitha Pinnacle," a small, now-buried volcanic pinnacle only 2 or 3 km from Site 593. Judging by seismic evidence, this volcanogenic deposit seems to have flowed several kilometers to the north of Site 593 and also seems to have been the only such event in this region during the Paleogene. The laminae of altered volcanic ash in the late Eocene probably represent air-fall deposits that were precursors to the submarine volcanic event that produced the pyroclastic deposits. Coeval volcanism occurred in the southern New Zealand region. The Deborah volcanics, South Canterbury, for instance, were also extruded at the time of the Eocene/Oligocene boundary. Similar volcanic pinnacles like "Lalitha" occur at other locations on the Challenger Plateau, and their structural relations with the sediments suggest that they were deposited at the same time, indicating that it was a period of widespread volcanism in the region.

Sedimentation continued over the Eocene/Oligocene boundary without break. The usual extinctions of planktonic foraminifers and calcareous nannoplankton index forms occurred. Benthic forms also show significant changes over this interval. White nannofossil oozes were deposited from the early Oligocene to the early middle Miocene. Sedimentation rates were noticeably low (4.6 m/m.y.) during the Eocene-Oligocene interval.

Other than some minor event leading to the deposition of a layer of hard ooze at the Oligocene/Miocene boundary, depositional conditions remained remarkably unchanged until the beginning of the middle Miocene. However, benthic faunas did evolve, indicating changes in bottom-water character.

Between 15.5 and 15 m.y. ago, there commenced deposition of a remarkable 25-m deposit of orange ooze which differs from the surrounding sediments only by its bright color. The top of this layer coincides with the upper boundary of NN5 and the subunit falls within the *Praeorbulina glomerosa curva* Zone; hence it is about 15.5 to 15 m.y. in age. The subunit thus seems to have immediately preceded the time of major ice build-up on Antarctica. The event that caused oxidation of this subunit must have altered the balance between available dissolved oxygen supplied to the seafloor and available organic carbon supplied to the infauna and bacteria within the sediment. It is possible that there was a brief development of a water mass front not far to the south of Site 593 that produced intermediate waters sufficiently highly oxygenated to prevent post-depositional reduction within the sediments. In the present day, oxygen charged Antarctic Intermediate Waters are produced a the Antarctic Convergence and flow toward the north a about 1000 m water depth (Figs. 5 and 13). The middle Miocene episode was relatively short-lived because the sediment had returned to a reduced state by about 1 m.y. ago. The oxidized sediment layer may, therefore represent a paleoceanographic change associated with the evolution of Antarctic glaciation. In this interval the character of the benthic fauna remains surprisingly constant. A few new forms occur, including *Melonis barleeanum, Bolivina anastomosa,* and *Uvigerina auberiana*. The small, hispid uvigerinids, however, occur in large numbers in Sample 593-42,CC and may be a reflection of the increased oxidation at that time.

Coincidentally, when deposition of the oxidized subunit ceased, sedimentation rates suddenly increased from 9.7 to 48.4 m/m.y. This increase may have resulted from increased biogenic productivity associated with stimulated circulation related to Miocene glaciation.

The large change occurs slightly later in the early Miocene (*P. glomerosa curva* to *Orbulina suturalis* zones). At this time, both the diversity and abundance of benthics increase. The rectuvigerinids disappear temporarily and seven new forms appear, at least four of which are cibicidids. *Nuttalides umbonifera*, a form correlated with deep water masses later in the Neogene, first occurs at this site.

High rates (48.4 m/m.y.) of sedimentation continued through the middle Miocene, with the deposition of relatively unchanging foraminifer-bearing nannofossil oozes to nannofossil oozes. These high rates diminished to 15 m/m.y. in the late Miocene to earliest Pliocene.

As in most of the sites drilled during Leg 90, there was a remarkable increase in sedimentation rates between 4 and 3 m.y. ago, in the late early Pliocene. Rates were 103 m/m.y. at Site 593. The paleoceanographic event that caused this increase remains unknown bu was almost certainly related to increased biogenic productivity. Beginning near the end of this interval, the percentage of foraminifers in the sediments increased.

The foraminifer-bearing nannofossil ooze that occurred at 3 m.y. in the sequence probably represents an interval when bottom currents in this area were strong enough to winnow some nannofossils from the sediment. The occurrence of an upper winnowed sequence at Site 593 i similar to the uppermost recovered sections at Sites 58 through 592, and probably coincides with a period o more intensive global oceanic circulation, perhaps re

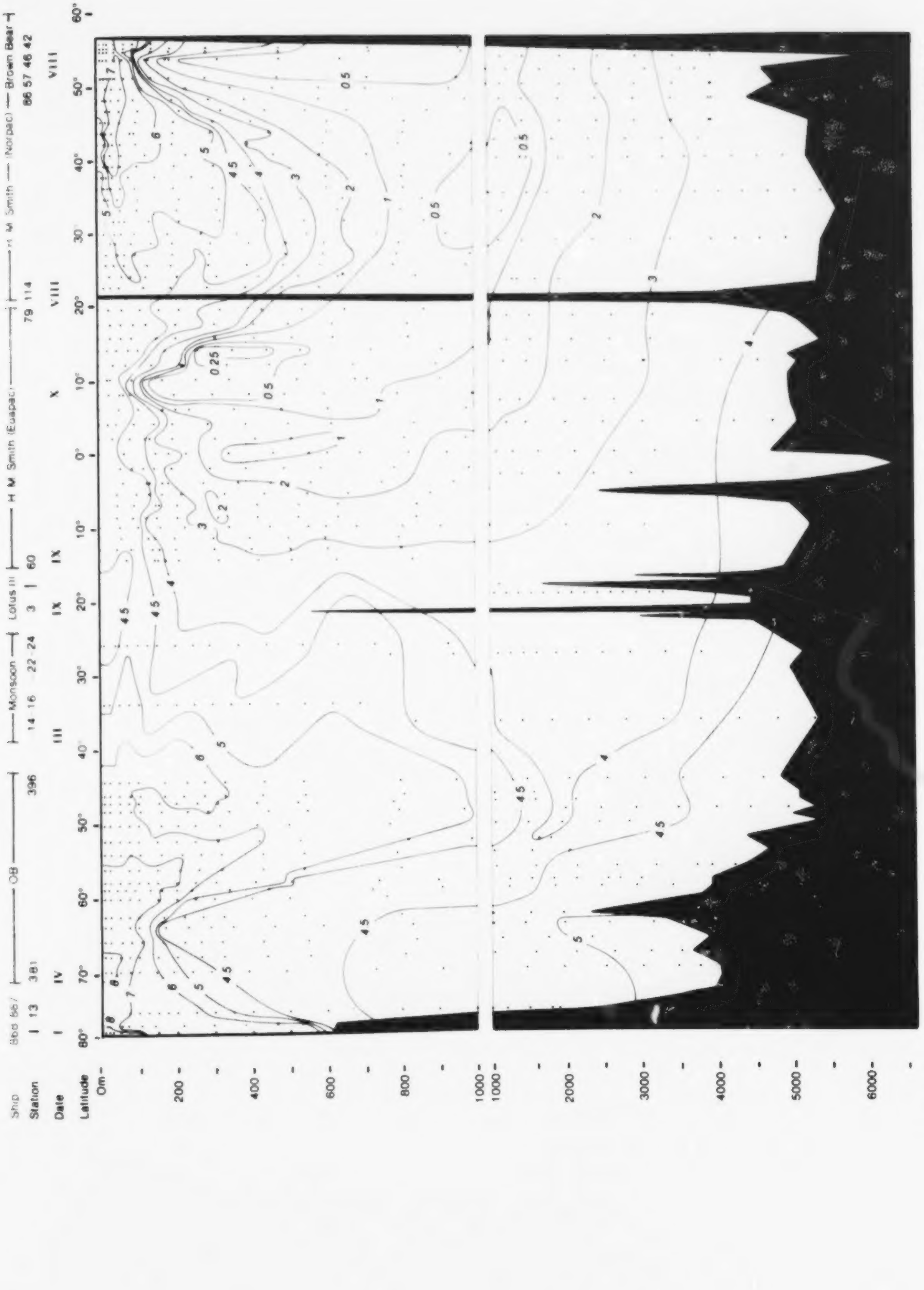


Figure 13. Dissolved-oxygen concentration (ml/l) along approximately 160°W from Antarctica to Alaska (reprinted with permission from Reid, 1965).

lated to the development of Northern Hemisphere glaciations. This led to a marked decrease in sedimentation rates (about 23 m/m.y.) through the late Pliocene to Quaternary.

The section terminates with the familiar late Quaternary veneer (0 to 6 m) of oxidized sediments.

REFERENCES

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet-water content, wet-bulk density, and porosity parameters by gravimetric and gamma-ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Hornibrook, N. B., 1982. Late Miocene to Pleistocene *Globorotalia* (Foraminiferid) from DSDP Leg 29, Site 284, southwest Pacific. *N.Z. J. Geol. Geophys.*, 25:83-99.

Jenkins, D. G., 1974. Initiation of the proto circum-Antarctic current. *Nature*, 252:371.

Kennett, J. P., Houtz, R. E., et al., 1975. *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office).

Kennett, J. P., Shackleton, N. J., Margolis, S. V., Goodney, D. E., Dudley, W. C., and Kroopnick, P. M., 1979. Late Cenozoic oxygen and carbon isotopic history and volcanic ash stratigraphy: DSDP Site 284, South Pacific. *Am. J. Sci.*, 279:52-69.

Kennett, J. P., and Vella, P. 1975. Late Cenozoic planktonic foraminifera and paleoceanography at DSDP Site 284 in the cool subtropical South Pacific. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 769-800.

Knox, G. A., 1970. Biological oceanography of the South Pacific. *In* Wooster, W. A. (Ed.), *Scientific Exploration of the South Pacific*: Washington (National Academy of Sciences), pp. 155-182.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports Scripps Institution of Oceanography, La Jolla, California.

Reid, J. L., Jr., 1965. *Intermediate Waters of the Pacific Ocean*. John Hopkins Oceanographic Studies, 2: Baltimore (Johns Hopkin University Press).

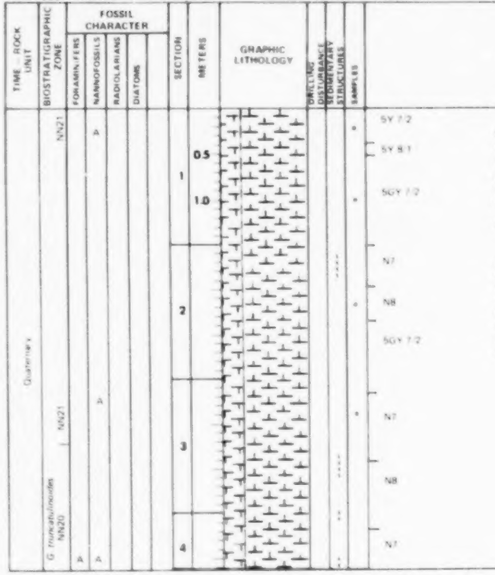
Shackleton, N. J., and Kennett, J. P., 1975. Late Cenozoic oxygen an carbon isotopic changes at DSDP Site 284: implications for glacia history of the northern hemisphere and Antarctic. *In* Kennett, J P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S Govt. Printing Office), 801-808.

Srinivasan, M. S., and Kennett, J. P., 1981. A review of Neogene plank tonic foraminiferal biostratigraphy: applications in the equatoria and South Pacific. *In* Warme, J. E., Douglas, R. G., and Winterer E. L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress* Soc. Econ. Paleontol. Mineral. Spec. Publ., 32:395-432.

Walker, R. G., 1967. Turbidite sedimentary structures and their rela tionship to proximal and distal depositional environments. *J. Sed Petrol.*, 37:25-43.

Date of Acceptance: 1 December 1983

SITE 593 HOLE CORE 1 CORED INTERVAL 0.0–5.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21
NN21
G. truncatulinoides
NN20
A
A
A
A
1
2
3
4
0.5
1.0
5Y 7/2
5Y 8/1
5GY 7/2
N7
N8
5GY 7/2
N7
N8
N7

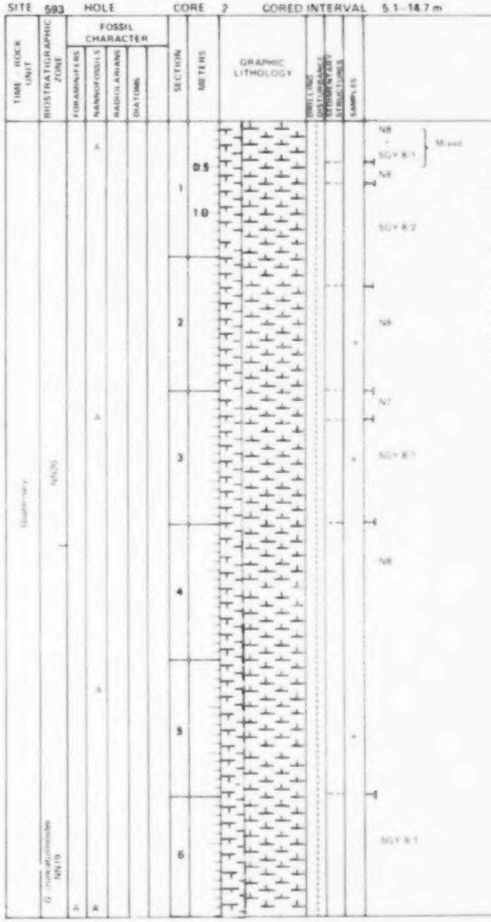
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, yellowish gray (5Y 7/2 and 5Y 8/1) in the first 0.50 m of Section 1. Then, sediment shows alternating zones of grayish yellow green (5GY 7/2) light gray (N7) and very light gray (N8) oozes. Grayish yellow green (5GY 7/2) burrows are present.

SMEAR SLIDE SUMMARY

	1, 20	1, 100	2, 67	3, 33
	D	D		D
Composition:				
Quartz	—	T	—	
Feldspar	—		T	
Volcanic glass	T	—	—	
Carbonate unspec.	—	T	—	T
Foraminifers	C	C	C	C
Calc. nannofossils	D	D	D	D
Sponge spicules	T	—	T	T

SITE 593 HOLE CORE 2 CORED INTERVAL 5.1–14.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN20
G. truncatulinoides
NN19
A
A
A
A
A
1
2
3
4
5
6
0.5
1.0
N8
5GY 8/1
Mixed
N8
5GY 8/2
N8
N7
5GY 8/1
N8
5GY 9/1

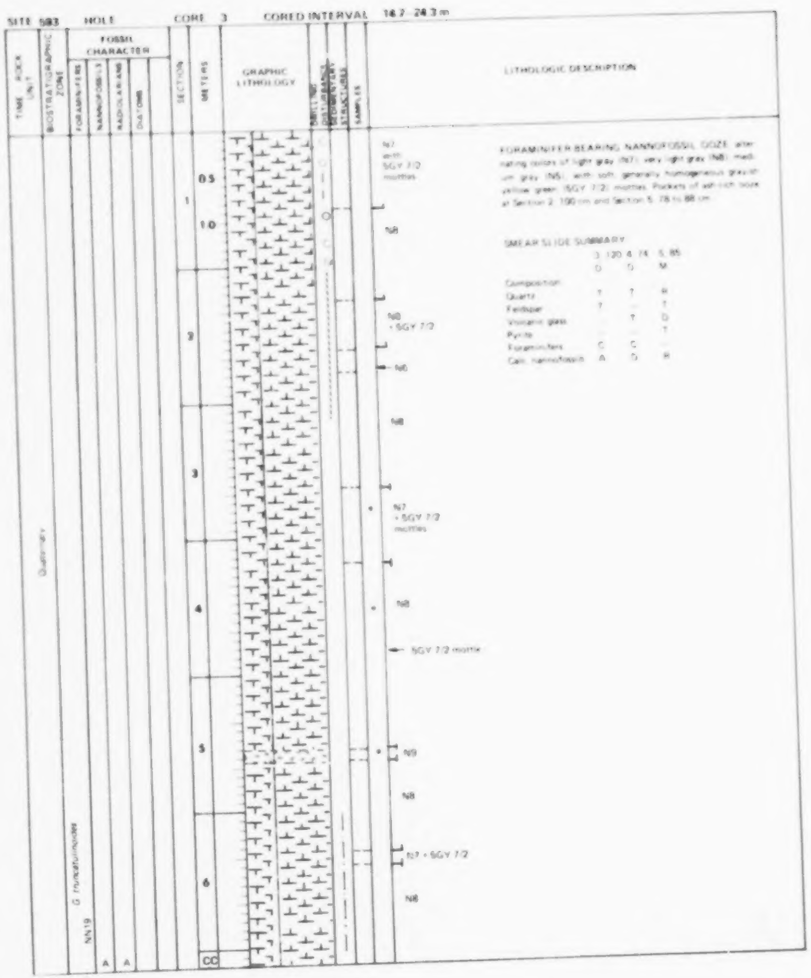
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), light gray (N7), light greenish gray (5GY 8/1), to very light greenish gray (5GY 9/1) interbeds, all with gradational contacts, soft. Mottles apparent in Sections 5 and 6, otherwise homogeneous. Coring disturbance throughout.

SMEAR SLIDE SUMMARY

	2, 96	3, 78	5, 79
	D	D	D
Composition:			
Quartz	T	T	T
Heavy minerals	—	—	T
Volcanic glass	—	T	T
Pyrite	—	T	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D

SITE 593 HOLE CORE 3 CORED INTERVAL 18.7–24.3 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
0.5
1.0
1
2
3
4
5
6
CC
N7 with 5GY 7/2 mottles
N8
N8 + 5GY 7/2
N6
N8
N7 + 5GY 7/2 mottles
N8
5GY 7/2 mottle
N9
N8
N7 + 5GY 7/2
N8

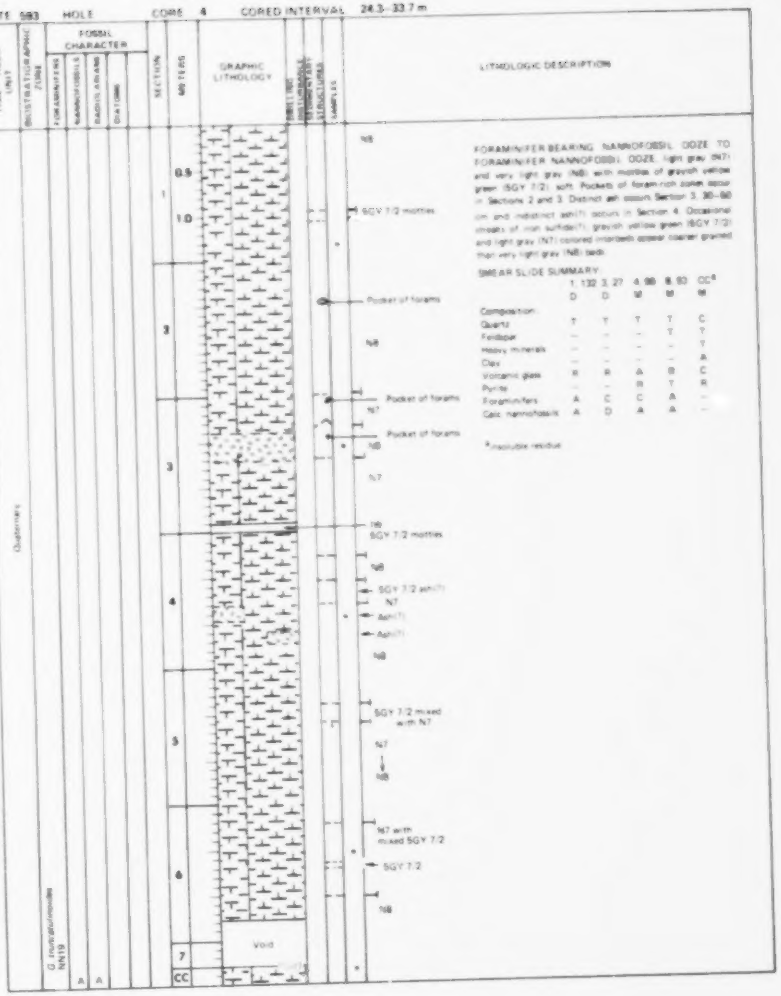
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, alternating colors of light gray (N7), very light gray (N8), medium gray (N5), with soft, generally homogeneous grayish yellow green (5GY 7/2) mottles. Pockets of ash-rich ooze at Section 2, 100 cm and Section 5, 78 to 88 cm.

SMEAR SLIDE SUMMARY

	3, 120 D	4, 74 D	5, 85 M
Composition:			
Quartz	T	T	R
Feldspar	T	—	T
Volcanic glass	—	T	D
Pyrite	—	—	T
Foraminifers	C	C	—
Calc. nannofossils	A	D	R

SITE 593 HOLE CORE 4 CORED INTERVAL 24.3–33.7 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN19
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
5GY 7/2 mottles
Pocket of forams
N8
Pocket of forams
N7
Pocket of forams
N8
N7
N8
5GY 7/2 mottles
N8
5GY 7/2 ash(?)
N7
Ash(?)
Ash(?)
N8
5GY 7/2 mixed with N7
N7
N8
N7 with mixed 5GY 7/2
5GY 7/2
N8

LITHOLOGIC DESCRIPTION

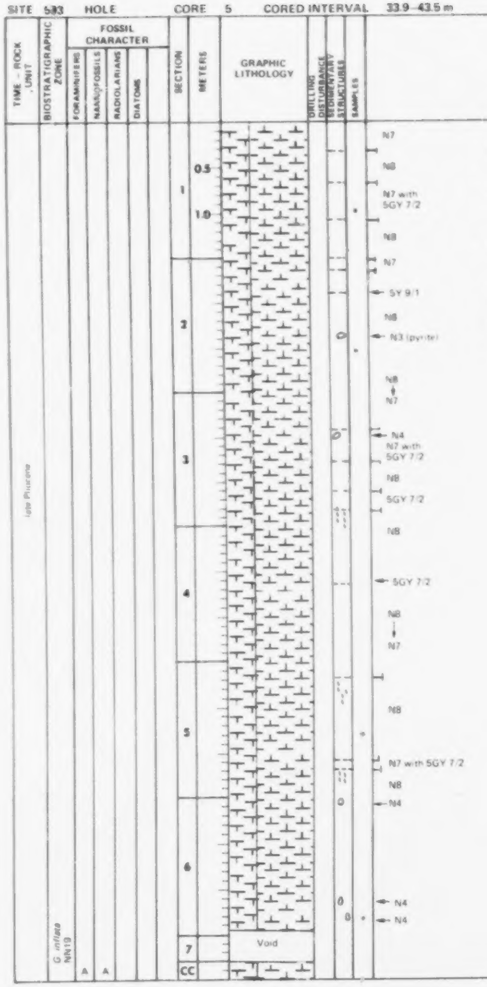
FORAMINIFER-BEARING NANNOFOSSIL OOZE TO FORAMINIFER NANNOFOSSIL OOZE, light gray (N7) and very light gray (N8) with mottles of grayish yellow green (5GY 7/2), soft. Pockets of foram-rich ooze occur in Sections 2 and 3. Distinct ash occurs Section 3, 30–80 cm and indistinct ash(?) occurs in Section 4. Occasional streaks of iron sulfide(?), grayish yellow green (5GY 7/2) and light gray (N7) colored interbeds appear coarser grained than very light gray (N8) beds.

SMEAR SLIDE SUMMARY

	1, 132 D	3, 27 D	4, 98 M	6, 93 M	CC[a] M
Composition:					
Quartz	T	T	T	T	C
Feldspar	—	—	—	T	T
Heavy minerals	—	—	—	—	T
Clay	—	—	—	—	A
Volcanic glass	R	R	A	R	C
Pyrite	—	—	R	T	R
Foraminifers	A	C	C	A	—
Calc. nannofossils	A	D	A	A	—

[a] Insoluble residue

SITE 593 HOLE CORE 5 CORED INTERVAL 33.9–43.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN19
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N7
N8
N7 with 5GY 7/2
N8
N7
5Y 9/1
N8
N3 (pyrite)
N8
N7
N4
N7 with 5GY 7/2
N8
5GY 7/2
N8
5GY 7/2
N8
N7
N8
N7 with 5GY 7/2
N8
N4
N4
N4

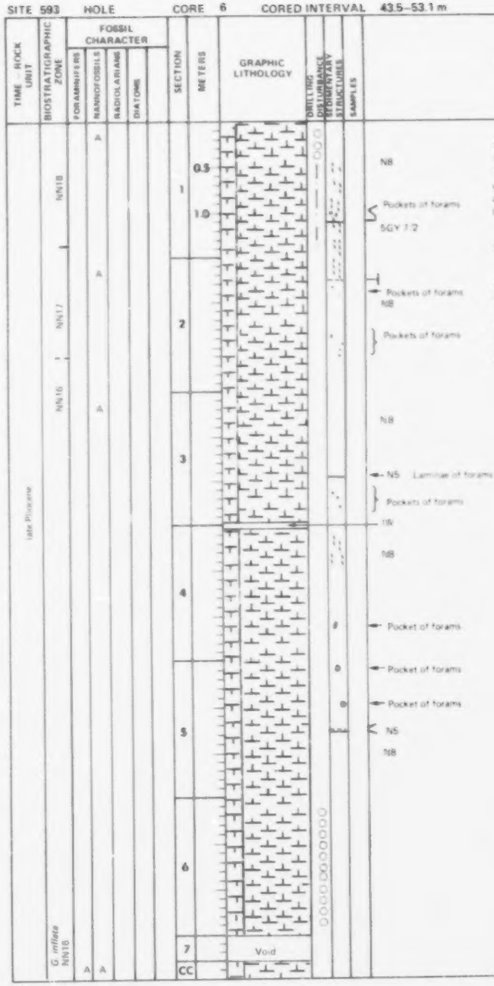
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, light gray (N7) to very light gray (N8) with mottled zones of mixed grayish yellow green (5GY 7/2). Soft; streaks and laminae iron sulfides(?) and pods of medium dark gray (N4) of pyrite(?). Mottling common and a few *Planolites* like burrows occur.

SMEAR SLIDE SUMMARY

	1, 95 D	2, 75 D	2, 80 M	5, 78 D	6, 133 M
Composition:					
Quartz	T	–	T	T	–
Volcanic glass	T	T	–	T	–
Pyrite	T	T	A	T	R
Foraminifers	A	A	C	C	C
Calc. nannofossils	A	A	A	D	A

SITE 593 HOLE CORE 6 CORED INTERVAL 43.5–53.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
NN18
NN17
NN16
G. inflata
NN18
A
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
Pockets of forams
5GY 7/2
Pockets of forams
N8
Pockets of forams
N8
N5 Laminae of forams
Pockets of forams
IW
N8
Pocket of forams
Pocket of forams
Pocket of forams
N5
N8

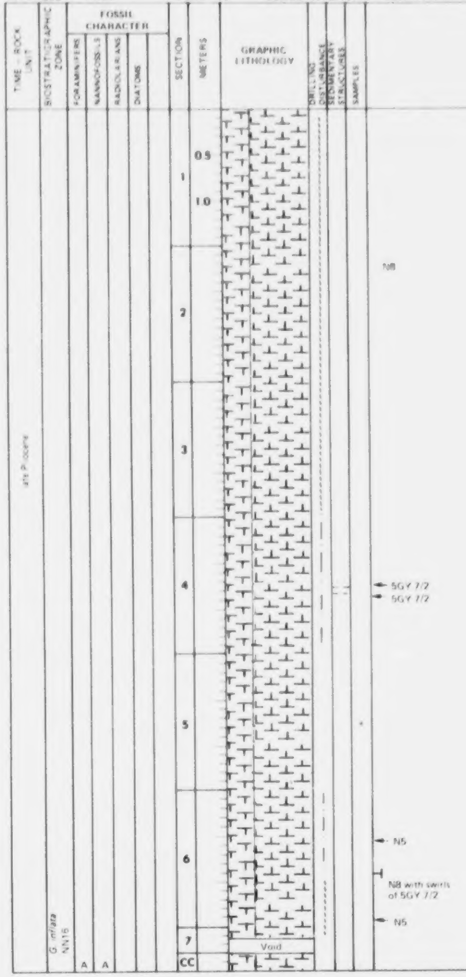
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with zones of grayish yellow green (5GY 7/2) mottling. Soft and homogeneous. Pockets of forams occur throughout the core. Rare tints of iron sulfides(?) and diffusion bands, especially in Section 3. Section 6 badly disturbed.

SMEAR SLIDE SUMMARY

	2, 9 D	3, 72 D
Composition:		
Quartz	T	–
Feldspar	T	T
Volcanic glass	T	T
Pyrite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 593 HOLE CORE 7 CORED INTERVAL 53.1–62.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN16
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
5GY 7/2
5GY 7/2
N5
N8 with swirls of 5GY 7/2
N5

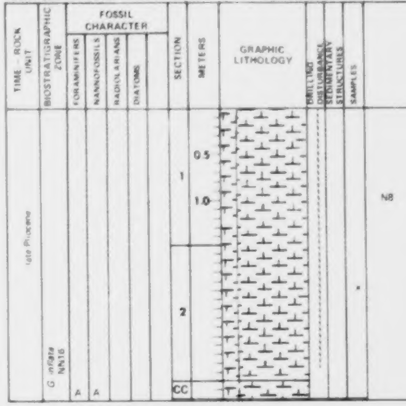
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, severe coring disturbance throughout. Light to very light gray (N8), soft, homogeneous. Streaks of iron sulfides(?). Faint hues of grayish yellow green (5GY 7/2) in Section 4.

SMEAR SLIDE SUMMARY

	5, 82
	D
Composition:	
Quartz	T
Feldspar	T
Volcanic glass	T
Foraminifers	C
Calc. nannofossils	D

SITE 593 HOLE CORE 8 CORED INTERVAL 62.7–72.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. inflata
NN16
A
A
1
2
CC
0.5
1.0
N8

LITHOLOGIC DESCRIPTION

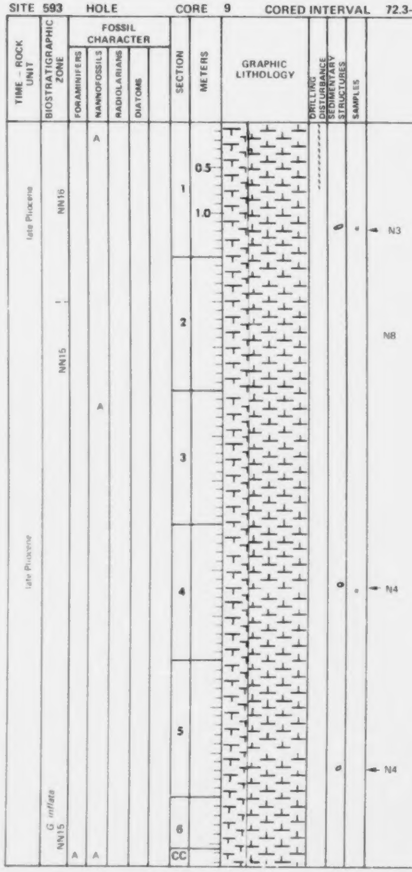
FORAMINIFER-BEARING NANNOFOSSIL OOZE, severe coring disturbance throughout core.

Very light gray (N8), soft, with streaks of medium dark gray (N4) throughout.

SMEAR SLIDE SUMMARY

	2, 63
	D
Composition:	
Pyrite	T
Foraminifers	C
Calc. nannofossils	D

SITE 593 HOLE CORE 9 CORED INTERVAL 72.3–81.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
late Pliocene
NN16
NN15
G. inflata NN15
A
A
A A
1
2
3
4
5
6
CC
0.5
1.0
N3
N8
N4
N4

LITHOLOGIC DESCRIPTION

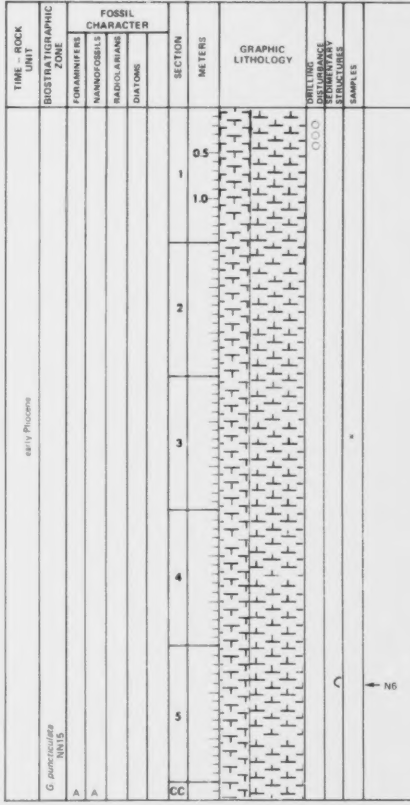
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous with streaks and blebs of iron sulfide dark gray (N3) scattered throughout. Diffusion bands of iron sulfide faintly show in Section 4.

SMEAR SLIDE SUMMARY

	1, 116	4, 73
	M	D
Composition:		
Quartz	–	T
Volcanic glass	T	T
Pyrite	A	T
Foraminifers	A	C
Calc. nannofossils	A	D

Core 10, 81.9–91.5 m, no recovery

SITE 593 HOLE CORE 11 CORED INTERVAL 91.5–101.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata NN15
A A
1
2
3
4
5
CC
0.5
1.0
N6

LITHOLOGIC DESCRIPTION

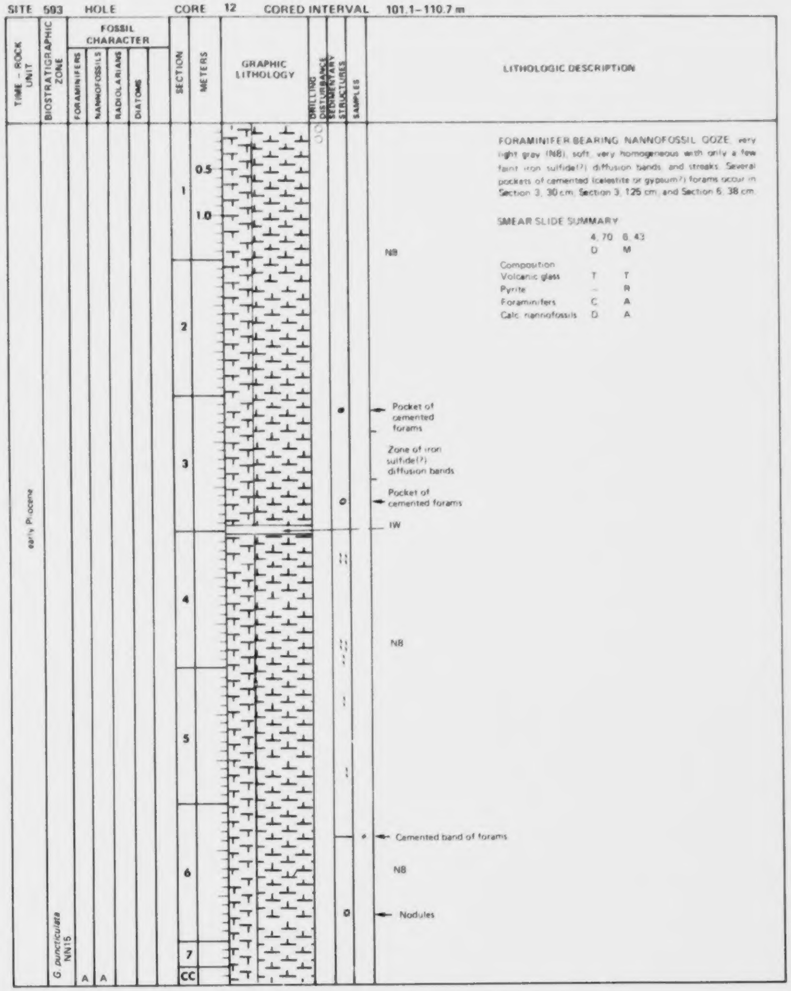
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, extremely homogeneous with only rare streaks and blebs of medium dark gray (N4) iron sulfide(?).

Nodule of cemented (celestite?) forams and pyrite(?) at Section 5, 40 cm.

SMEAR SLIDE SUMMARY

	3, 68
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D

SITE 593 HOLE CORE 12 CORED INTERVAL 101.1–110.7 m

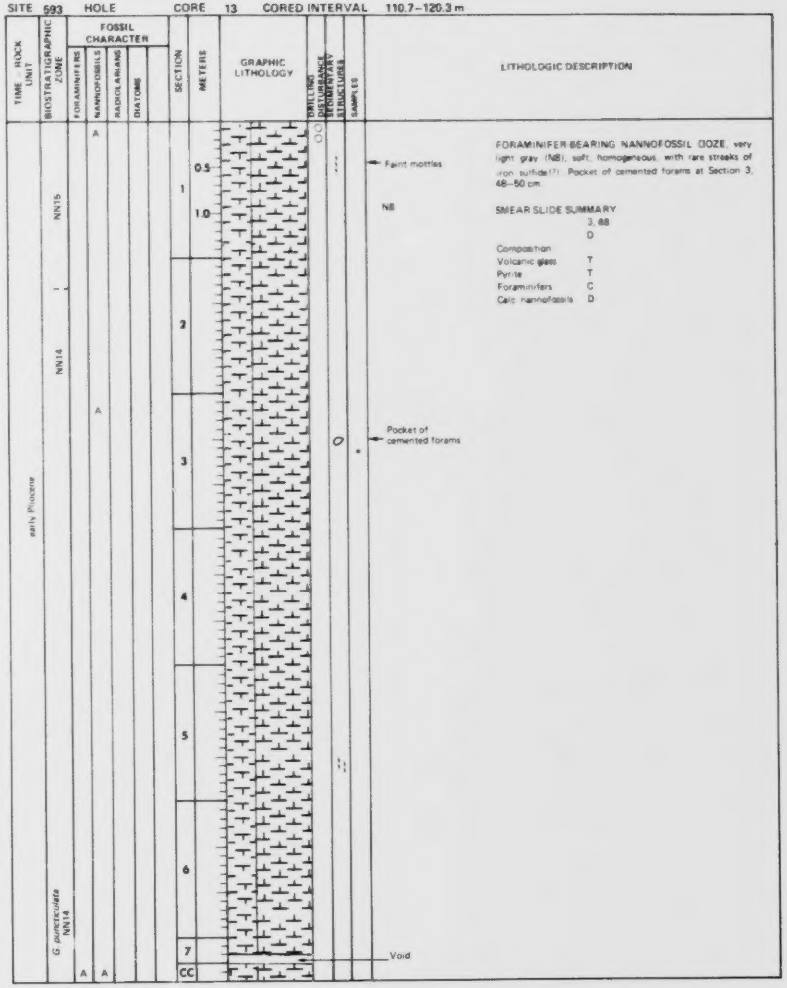

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
G. puncticulata NN15
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
Pocket of cemented forams
Zone of iron sulfide(?) diffusion bands
Pocket of cemented forams
IW
N8
Cemented band of forams
N8
Nodules

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous with only a few faint iron sulfide(?) diffusion bands, and streaks. Several pockets of cemented (celestite or gypsum?) forams occur in Section 3, 30 cm, Section 3, 125 cm, and Section 6, 38 cm.

SMEAR SLIDE SUMMARY

	4, 70	6, 43
	D	M
Composition		
Volcanic glass	T	T
Pyrite	–	R
Foraminifers	C	A
Calc. nannofossils	D	A

SITE 593 HOLE CORE 13 CORED INTERVAL 110.7–120.3 m

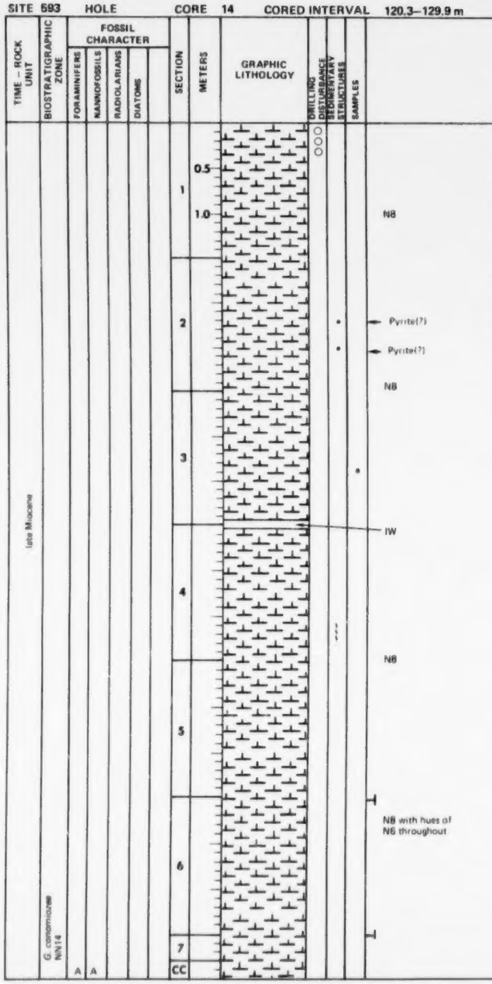

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
NN14
G. puncticulata NN14
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Faint mottles
N8
Pocket of cemented forams
Void

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, with rare streaks of iron sulfide(?). Pocket of cemented forams at Section 3, 48–50 cm.

SMEAR SLIDE SUMMARY

	3, 88
	D
Composition	
Volcanic glass	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D

SITE 593 HOLE CORE 14 CORED INTERVAL 120.3–129.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. conomiozea
NN14
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N8
Pyrite(?)
Pyrite(?)
N8
IW
N8
N8 with hues of
N6 throughout

LITHOLOGIC DESCRIPTION

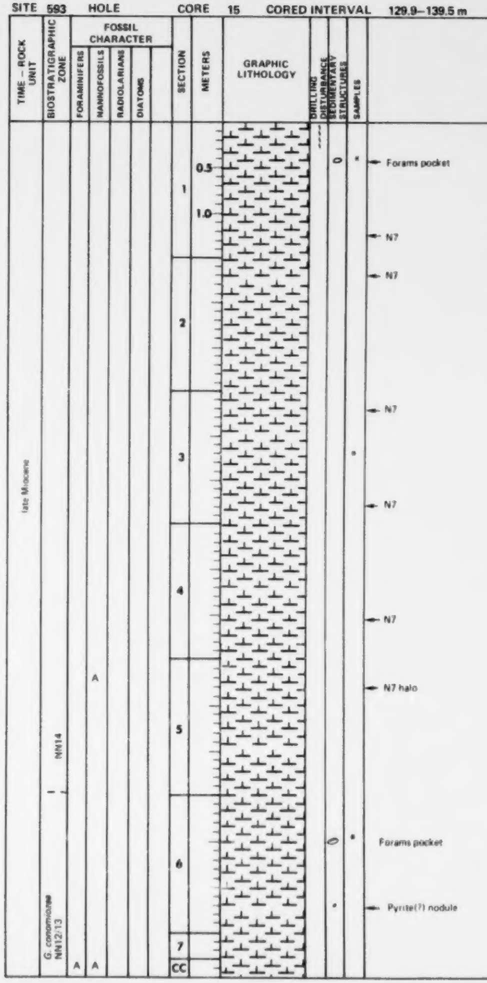
NANNOFOSSIL OOZE, very light gray (N8) with rare faint hues of medium light gray (N6) from iron sulfides(?). Soft and very homogeneous throughout.

Strong H_2S odor when split.

SMEAR SLIDE SUMMARY:

	3, 82
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 15 CORED INTERVAL 129.9–139.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN14
G. conomiozea
NN12/13
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Forams pocket
N7
N7
N7
N7
N7
N7 halo
Forams pocket
Pyrite(?) nodule

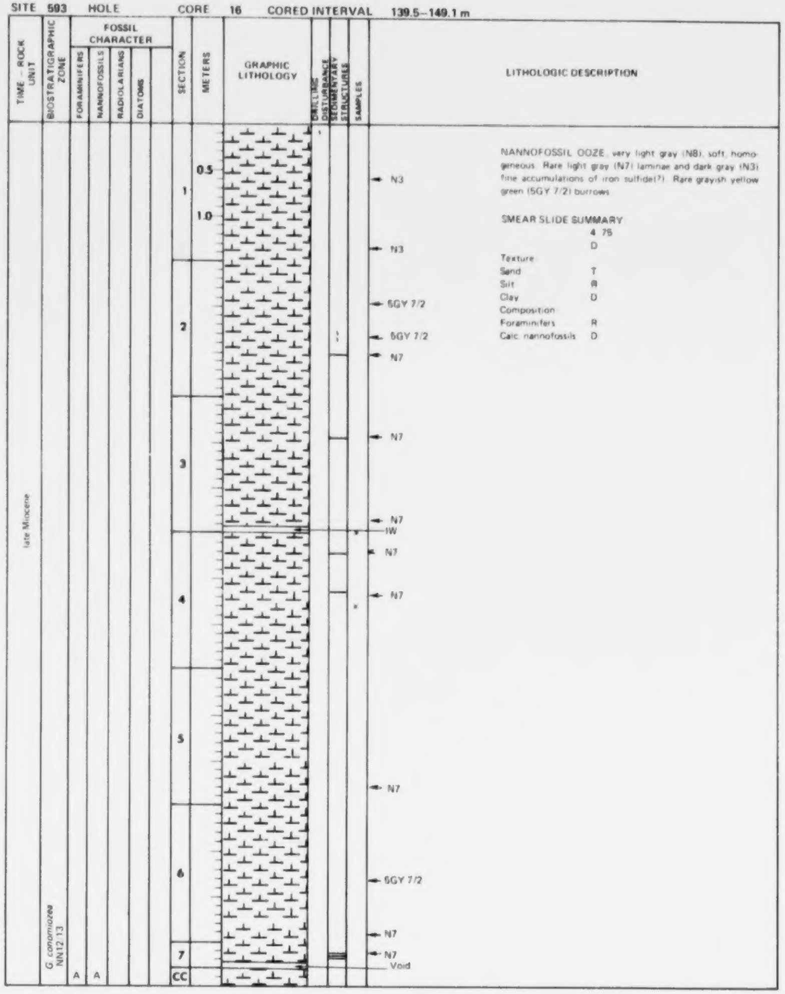
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, with rare light gray (N7) laminae of iron sulfide.

SMEAR SLIDE SUMMARY:

	3, 70	1, 40	6, 45
	D	M	M
Texture:			
Sand	R	C	C
Silt	C	C	C
Clay	D	D	C
Composition:			
Pyrite	–	–	T
Foraminifers	R	C	A
Calc. nannofossils	D	D	C
Sponge spicules	–	T	T

SITE 593 HOLE CORE 16 CORED INTERVAL 139.5–149.1 m

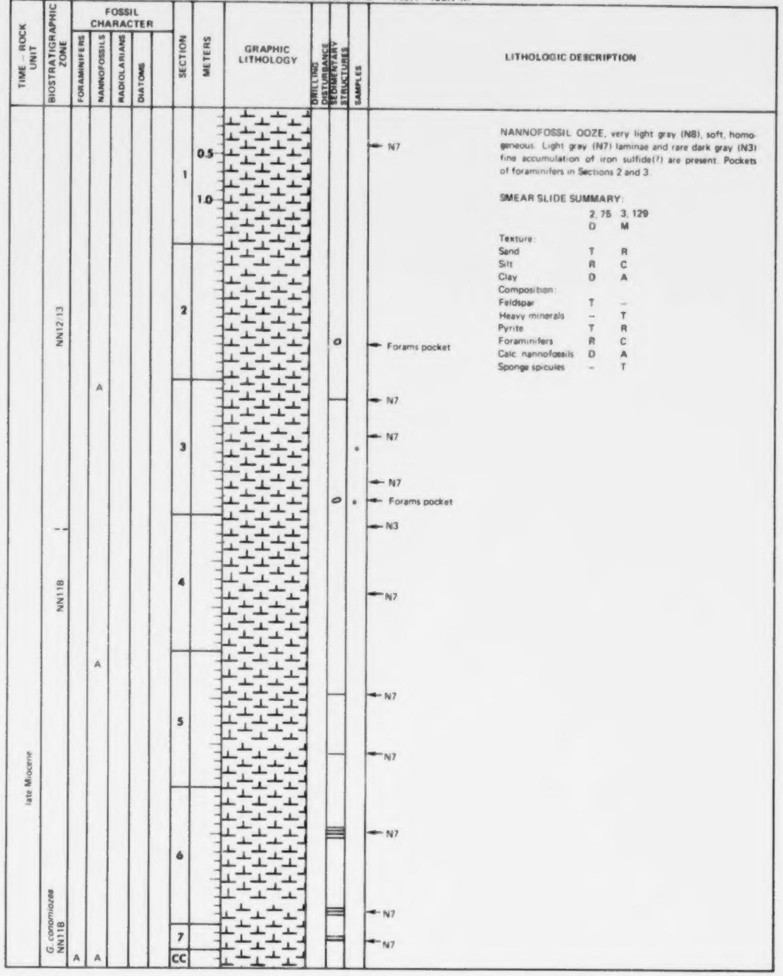

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. conomiozea
NN12/13
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N3
N3
5GY 7/2
5GY 7/2
N7
N7
N7
IW
N7
N7
N7
5GY 7/2
N7
N7
Void

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Rare light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Rare grayish yellow green (5GY 7/2) burrows.

SMEAR SLIDE SUMMARY:

	4, 75
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 17 CORED INTERVAL 149.1–158.7 m

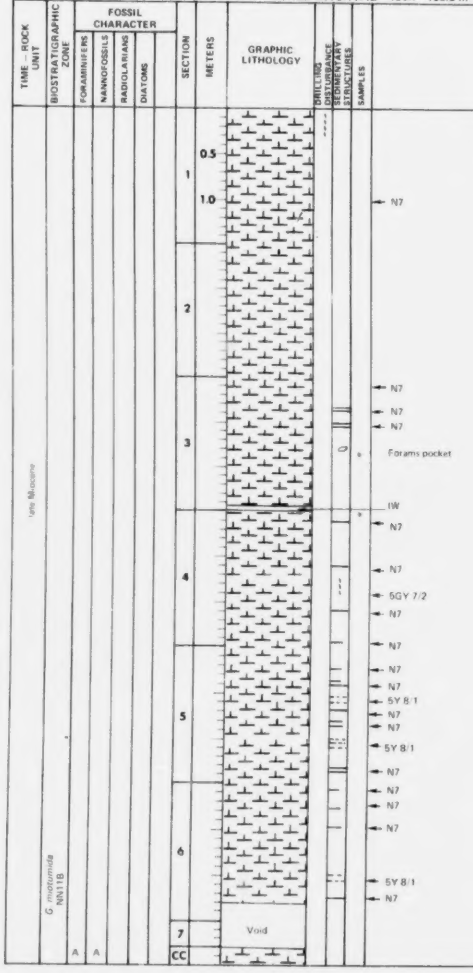

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN12/13
NN11B
G. conomiozea
NN11B
A
A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
Forams pocket
N7
N7
N7
Forams pocket
N3
N7
N7
N7
N7
N7
N7

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and rare dark gray (N3) fine accumulation of iron sulfide(?) are present. Pockets of foraminifers in Sections 2 and 3.

SMEAR SLIDE SUMMARY:

	2, 75	3, 129
	D	M
Texture:		
Sand	T	R
Silt	R	C
Clay	D	A
Composition:		
Feldspar	T	–
Heavy minerals	–	T
Pyrite	T	R
Foraminifers	R	C
Calc. nannofossils	D	A
Sponge spicules	–	T

SITE 593 HOLE CORE 18 CORED INTERVAL 158.7–168.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N7
N7
N7
N7
Forams pocket
IW
N7
N7
5GY 7/2
N7
N7
N7
N7
5Y 8/1
N7
N7
5Y 8/1
N7
N7
N7
N7
5Y 8/1
N7

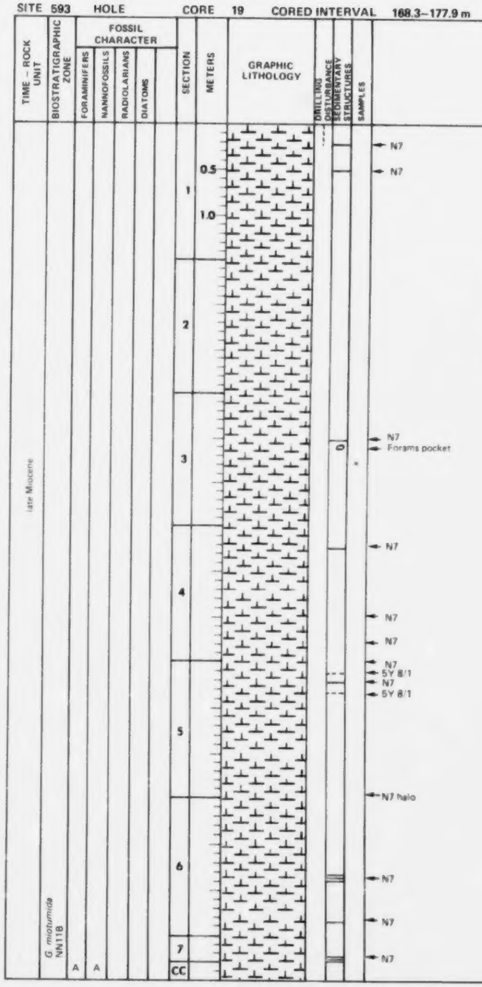
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Grayish yellow green (5GY 7/2) burrows, foraminifers pockets and discrete yellowish gray (5Y 8/1) laminae are present.

SMEAR SLIDE SUMMARY

	3, 65	3, 77
	D	M
Composition:		
Feldspar	T	—
Pyrite	—	T
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 593 HOLE CORE 19 CORED INTERVAL 168.3–177.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N7
N7
Forams pocket
N7
N7
N7
N7
5Y 8/1
N7
5Y 8/1
N7 halo
N7
N7
N7

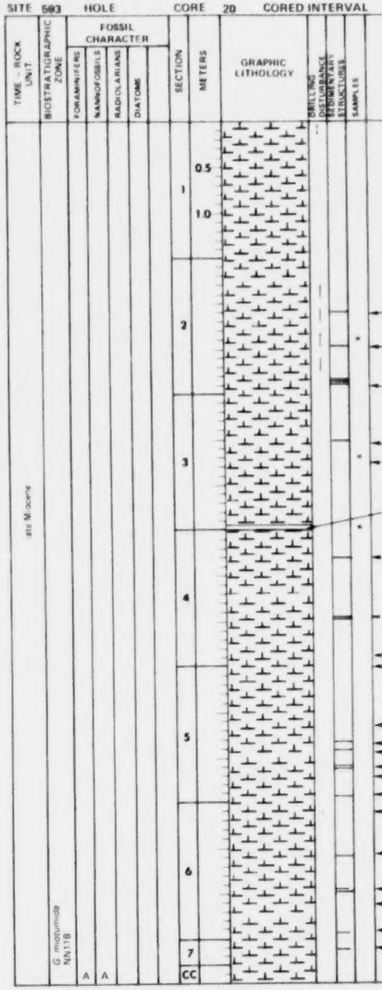
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Foraminifers pockets and discrete yellowish gray (5Y 8/1) laminae are present.

SMEAR SLIDE SUMMARY:

	3, 75
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Heavy minerals	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 20 CORED INTERVAL 177.9–189.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N7
N7
N7
N7
IW
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7
N7

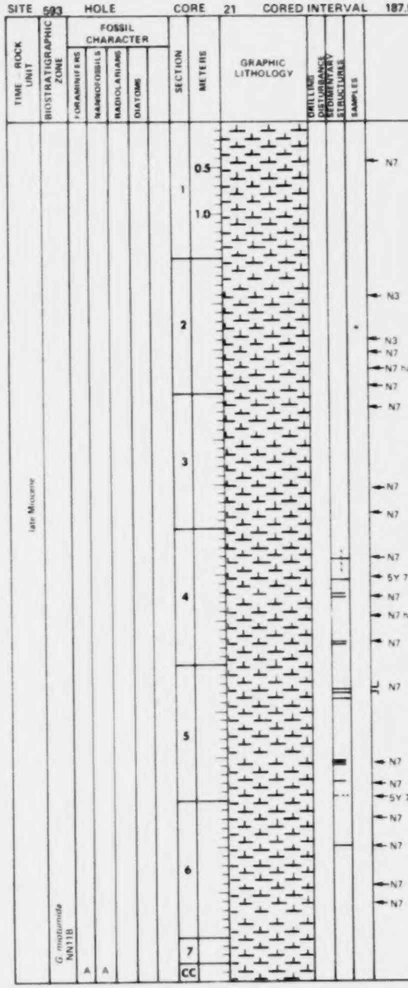
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae of iron sulfide(?) are present.

SMEAR SLIDE SUMMARY

	3, 70	2, 74
	D	M
Texture:		
Silt	R	R
Clay	D	D
Composition:		
Quartz	T	–
Feldspar	T	T
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 593 HOLE CORE 21 CORED INTERVAL 187.5–197.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN11B
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N3
N3
N7
N7 halo
N7
N7
N7
N7
N7
5Y 7/2
N7
N7 halo
N7
N7
N7
N7
5Y 7/2
N7
N7
N7
N7

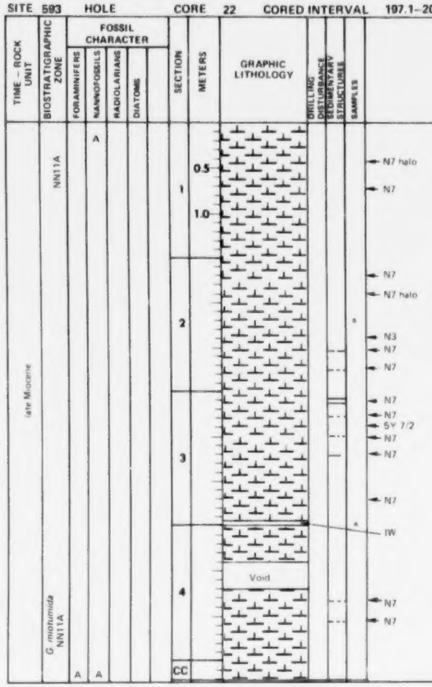
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?) are present, as well as rare yellowish gray (5Y 7/2) burrows and laminae.

SMEAR SLIDE SUMMARY

	2, 75	5, 144
	D	M
Texture:		
Sand	–	A
Silt	R	A
Clay	D	A
Composition:		
Quartz	T	–
Heavy minerals	T	–
Volcanic glass	T	–
Foraminifers	R	A
Calc. nannofossils	D	A

SITE 593 HOLE CORE 22 CORED INTERVAL 197.1–206.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11A
G. miotumida
NN11A
A
A
A
1
2
3
4
CC
0.5
1.0
Void
N7 halo
N7
N7
N7 halo
N3
N7
N7
N7
N7
5Y 7/2
N7
N7
N7
IW
N7
N7

LITHOLOGIC DESCRIPTION

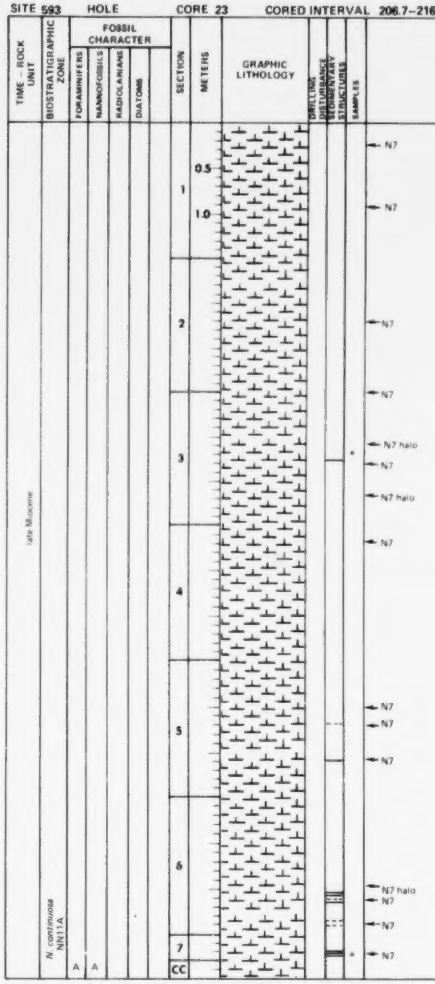
Non oriented core

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Rare yellowish gray (5Y 7/2) burrows are present. Void in Section 4 between 0.40 and 0.70 m is due to drilling.

SMEAR SLIDE SUMMARY

	2, 70
	D
Texture	
Sand	T
Silt	R
Clay	D
Composition	
Feldspar	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 23 CORED INTERVAL 206.7–216.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN11A
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N7
N7
N7
N7 halo
N7
N7 halo
N7
N7
N7
N7
N7 halo
N7
N7
N7

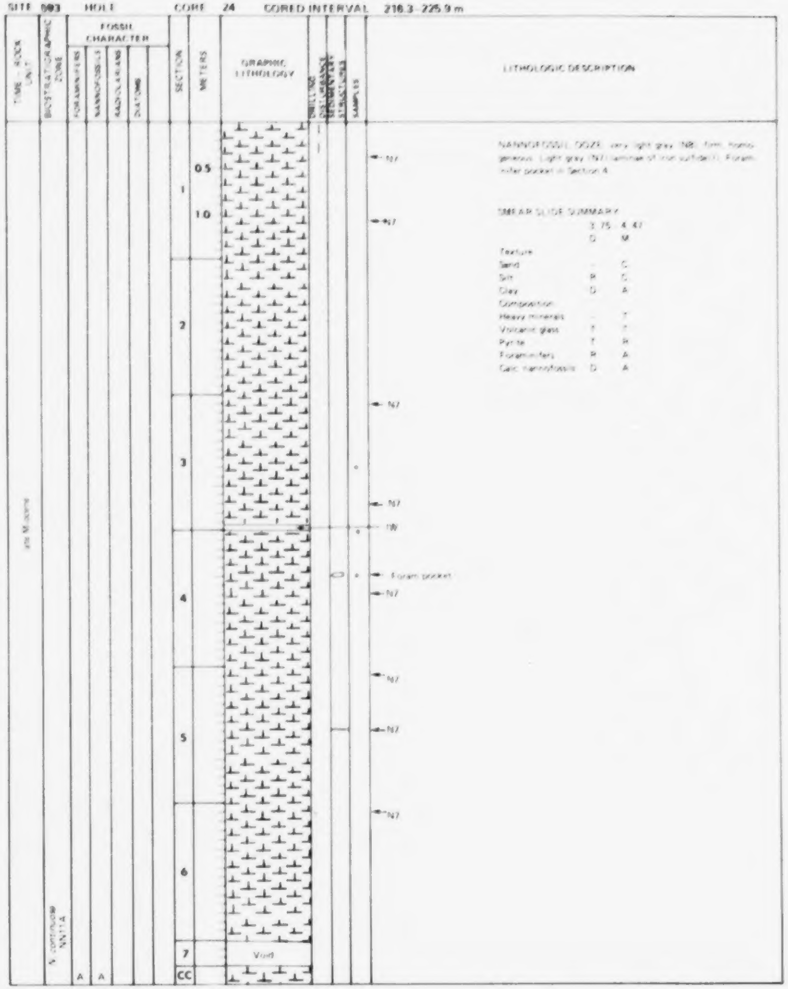
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous, light gray (N7) laminae and halos of iron sulfide(?) occur throughout core.

SMEAR SLIDE SUMMARY

	3, 65	7, 20
	D	M
Texture		
Silt	R	R
Clay	D	D
Composition		
Feldspar	T	–
Heavy minerals	T	–
Pyrite	—	T
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 593 HOLE CORE 24 CORED INTERVAL 216.3–225.9 m

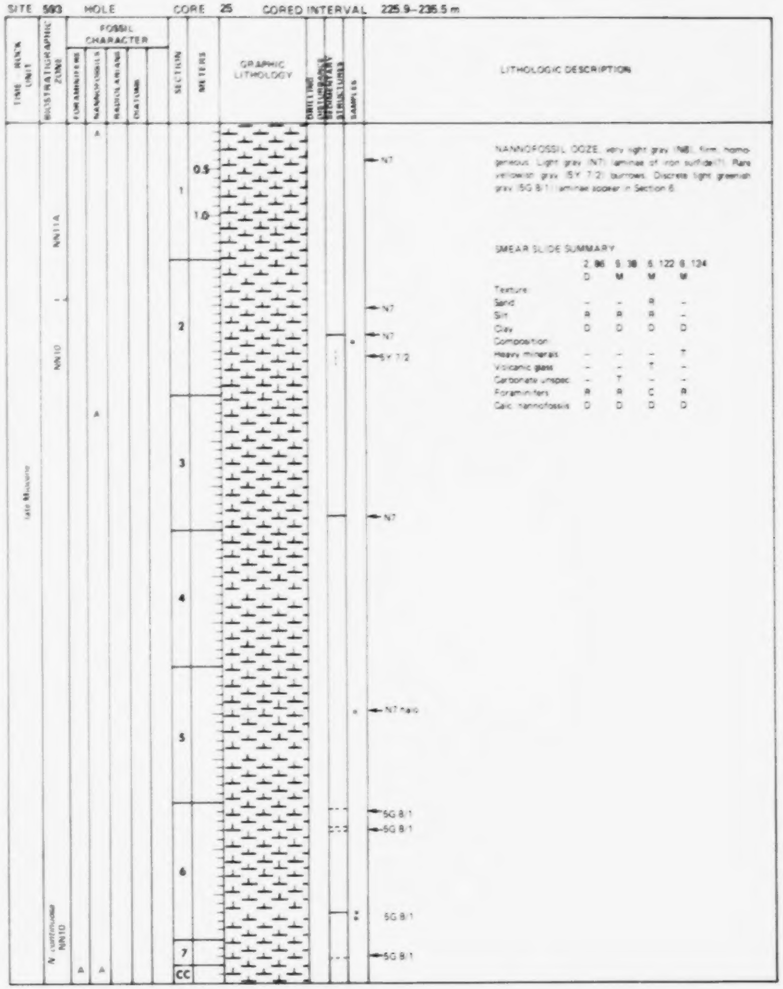

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
N. continuosa NN11A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7
N7
N7
N7
IW
Foram pocket
N7
N7
N7
N7

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae of iron sulfide(?). Foraminifer pocket in Section 4.

SMEAR SLIDE SUMMARY

	3, 75	4, 47
	D	M
Texture:		
Sand	–	C
Silt	R	C
Clay	D	A
Composition:		
Heavy minerals	–	T
Volcanic glass	T	T
Pyrite	T	R
Foraminifers	R	A
Calc. nannofossils	D	A

SITE 593 HOLE CORE 25 CORED INTERVAL 225.9–235.5 m

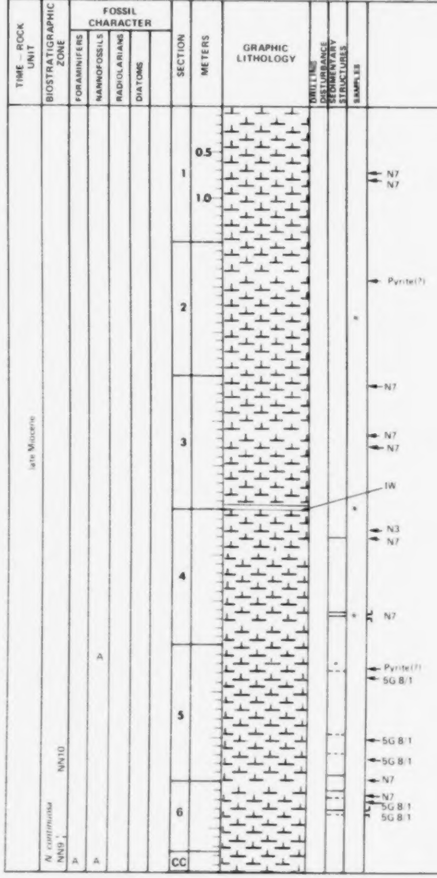

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
NN11A
NN10
N. continuosa NN10
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N7
N7
5Y 7/2
N7
N7 halo
5G 8/1
5G 8/1
5G 8/1
5G 8/1

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae of iron sulfide(?). Rare yellowish gray (5Y 7/2) burrows. Discrete light greenish gray (5G 8/1) laminae sooner in Section 6.

SMEAR SLIDE SUMMARY

	2, 86	5, 38	6, 122	6, 124
	D	M	M	M
Texture:				
Sand	–	–	R	–
Silt	R	R	R	–
Clay	D	D	D	D
Composition:				
Heavy minerals	–	–	–	T
Volcanic glass	–	–	T	–
Carbonate unspec.	–	T	–	–
Foraminifers	R	R	C	R
Calc. nannofossils	D	D	D	D

SITE 593 HOLE CORE 26 CORED INTERVAL 236.5–245.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN10
N. continuosa
NN9
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N7
N7
Pyrite(?)
N7
N7
N7
IW
N3
N7
N7
Pyrite(?)
5G 8/1
5G 8/1
5G 8/1
N7
N7
5G 8/1
5G 8/1

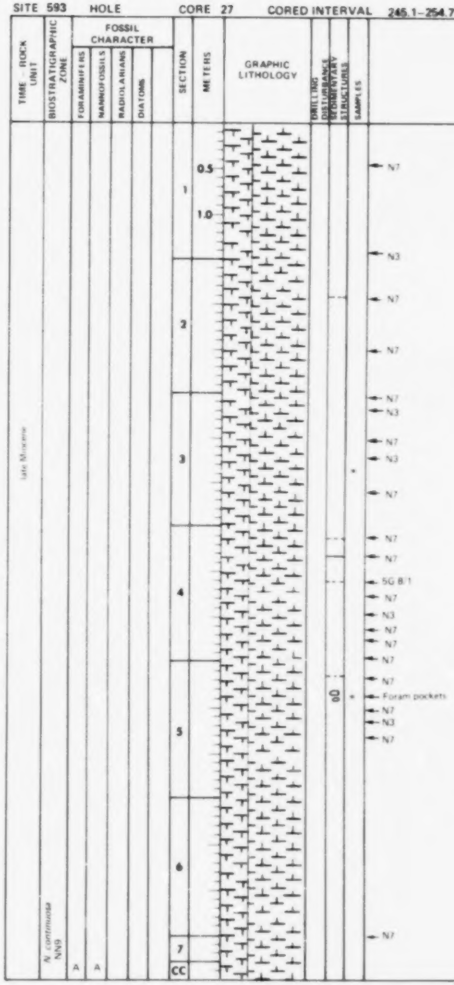
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N6), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Pyrite(?) nodules are present in Sections 2 and 5. Light greenish gray (5G 8/1) laminae are present in Sections 5 and 6.

SMEAR SLIDE SUMMARY

	2, 83	4, 127	6, 29
	D	M	M
Texture:			
Silt	R	R	C
Clay	D	D	D
Composition:			
Heavy minerals	T	–	T
Foraminifers	R	R	C
Calc. nannofossils	D	D	D

SITE 593 HOLE CORE 27 CORED INTERVAL 245.1–254.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN9
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N3
N7
N7
N7
N3
N7
N3
N7
N7
N7
5G 8/1
N7
N3
N7
N7
N7
N7
Foram pockets
N7
N3
N7
N7

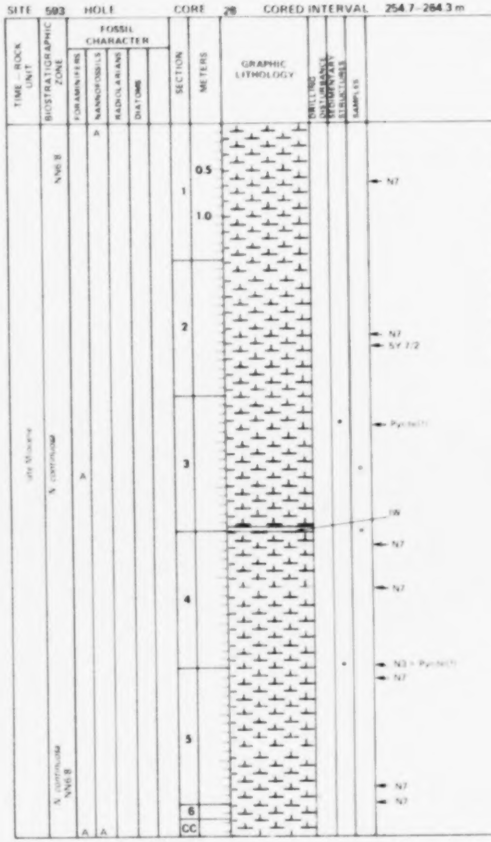
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Foraminifer pockets are present in Section 5.

SMEAR SLIDE SUMMARY

	3, 80	5, 29
	D	M
Texture:		
Sand	R	C
Silt	C	C
Clay	D	A
Composition:		
Feldspar	T	–
Heavy minerals	–	T
Volcanic glass	T	–
Carbonate unspec.	T	–
Foraminifers	C	A
Calc. nannofossils	D	A
Sponge spicules	T	–

SITE 593 HOLE CORE 28 CORED INTERVAL 254.7–264.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN6.8
N. continuosa
N. continuosa
NN6.8
A
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
N7
N7
5Y 7/2
Pyrite(?)
IW
N7
N7
N3 + Pyrite(?)
N7
N7
N3

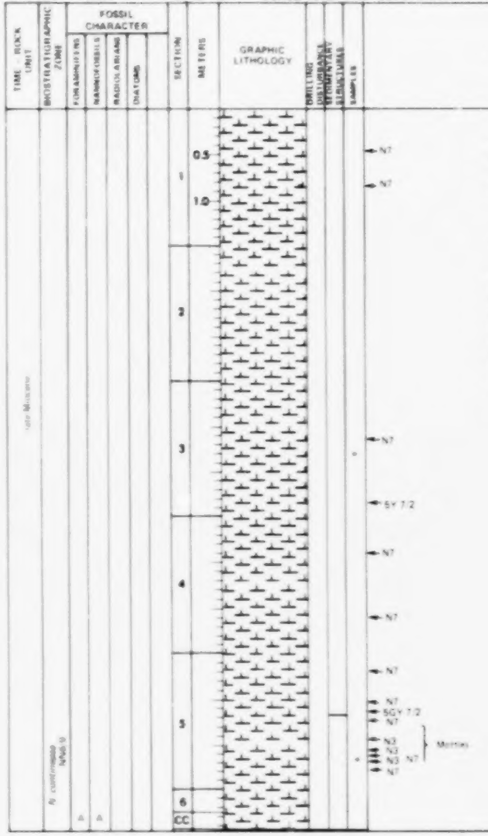
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Pyrite(?) nodules in Sections 3 and 4.

SMEAR SLIDE SUMMARY

	3, 80
	D
Texture:	
Silt	R
Clay	D
Composition:	
Heavy minerals	T
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

SITE 593 HOLE CORE 29 CORED INTERVAL 264.3–273.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN6.9
A
A
0.5
1.0
1
2
3
4
5
6
CC
N7
N7
N7
5Y 7/2
N7
N7
N7
N7
5GY 7/2
N7
N3
N3
N3
N7
N7
Mottles

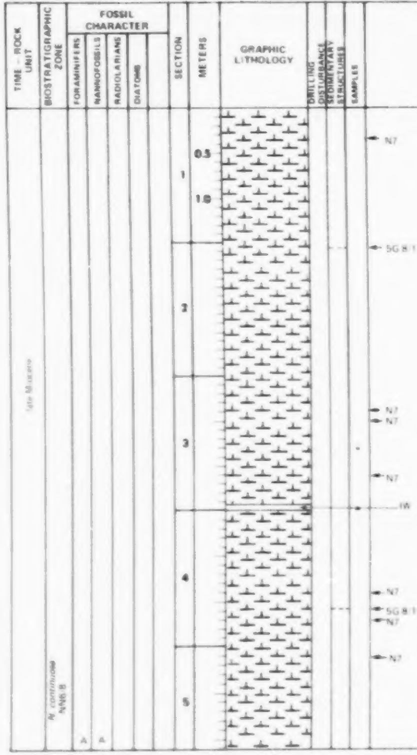
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) burrows and laminae, and dark gray (N3) fine accumulations of iron sulfide(?). Rare yellowish gray (5Y 7/2) and grayish yellow green (5GY 7/2) burrows.

SMEAR SLIDE SUMMARY

	3, 80	5, 108
	D	M
Texture:		
Silt	R	R
Clay	D	D
Composition:		
Quartz	–	T/R
Heavy minerals	T	T
Volcanic glass	T	T
Foraminifers	R/C	R
Calc. nannofossils	D	D
Sponge spicules	T	–

SITE 593 HOLE CORE 30 CORED INTERVAL 273.9–283.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN6-8
A
A
1
2
3
4
5
0.5
1.0
N7
5G 8/1
N7
N7
N7
IW
N7
5G 8/1
N7
N7

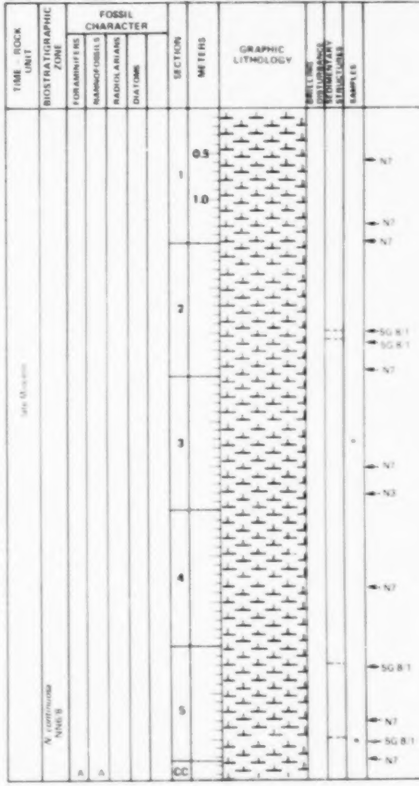
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae and accumulations of iron sulfide(?). Discrete light greenish gray (5G 8/1) laminae in Sections 2 and 4.

SMEAR SLIDE SUMMARY

	3, 80
	D
Texture:	
Silt	R
Clay	D
Composition:	
Quartz	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

SITE 593 HOLE CORE 31 CORED INTERVAL 283.5–293.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN6-8
A
A
1
2
3
4
5
CC
0.5
1.0
N7
N7
N7
5G 8/1
5G 8/1
N7
N7
N3
N7
5G 8/1
N7
5G 8/1
N7

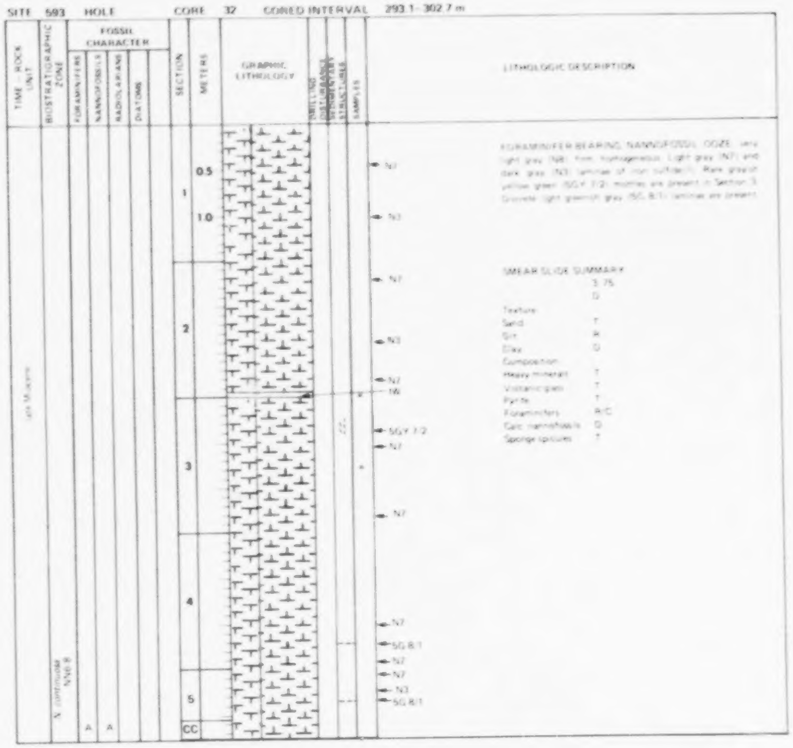
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide(?). Discrete light greenish gray (5G 8/1) laminae are present.

SMEAR SLIDE SUMMARY

	3, 75	5, 80
	D	M
Texture:		
Silt	R	C
Clay	D	D
Composition:		
Quartz	T	T
Feldspar	T	—
Volcanic glass	T	—
Foraminifers	R/C	C
Calc. nannofossils	D	D
Radiolarians	—	T

SITE 593 HOLE CORE 32 CORED INTERVAL 293.1–302.7 m


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
NN 8
A
A
0.5
1.0
1
2
3
4
5
CC
N7
N3
N7
N3
N7
N6
5GY 7/2
N7
N7
N7
5G 8/1
N7
N7
N3
5G 8/1

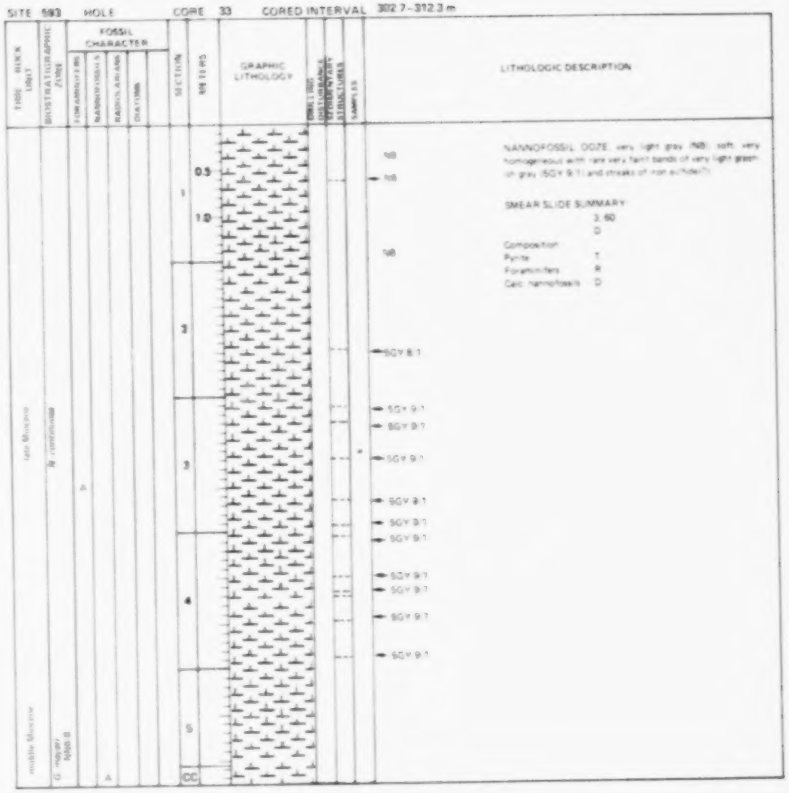
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), firm, homogeneous. Light gray (N7) and dark gray (N3) laminae of iron sulfide(?). Rare grayish yellow green (5GY 7/2) mottles are present in Section 3. Discrete light greenish gray (5G 8/1) laminae are present.

SMEAR SLIDE SUMMARY

	3, 75
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Heavy minerals	T
Volcanic glass	T
Pyrite	T
Foraminifers	R/C
Calc. nannofossils	D
Sponge spicules	T

SITE 593 HOLE CORE 33 CORED INTERVAL 302.7–312.3 m


TIME — ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
N. continuosa
middle Miocene
G. mayeri
NN8 8
A
A
0.5
1.0
1
2
3
4
5
CC
N8
N8
N8
5GY 8/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1
5GY 9/1

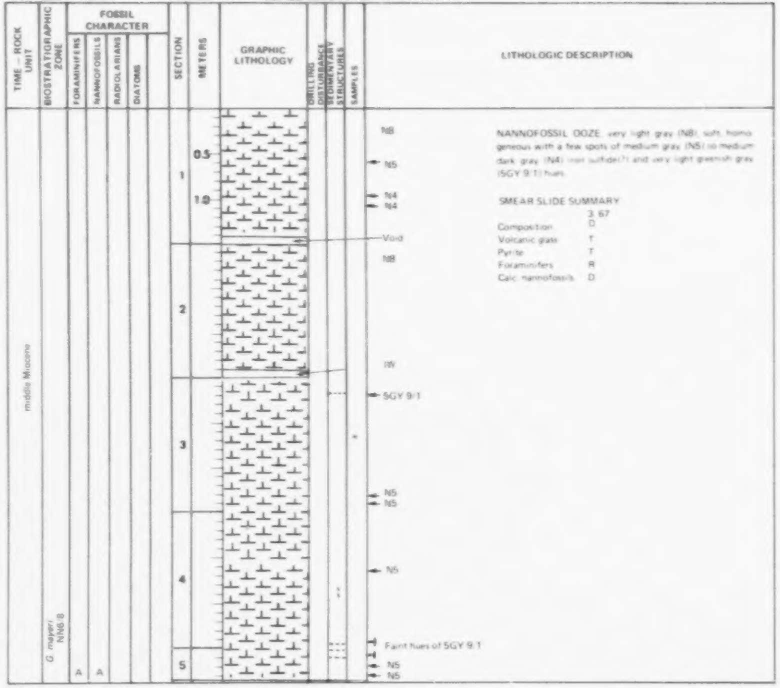
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous with rare very faint bands of very light greenish gray (5GY 9/1) and streaks of iron sulfide(?).

SMEAR SLIDE SUMMARY

	3, 60
	D
Composition:	
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 34 CORED INTERVAL 312.3–321.9 m

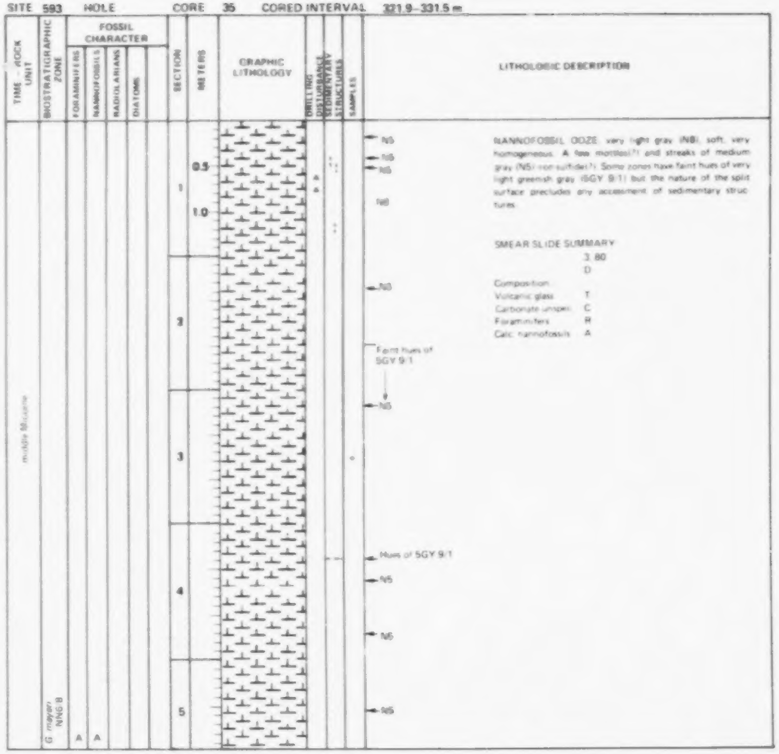

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN6-8
A
A
1
2
3
4
5
0.5
1.0
N8
N5
N4
N4
Void
N8
N9
5GY 9/1
N5
N5
N5
Faint hues of 5GY 9/1
N5
N5

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous with a few spots of medium gray (N5) to medium dark gray (N4) iron sulfide(?) and very light greenish gray (5GY 9/1) hues.

SMEAR SLIDE SUMMARY

	3, 67
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 35 CORED INTERVAL 321.9–331.5 m

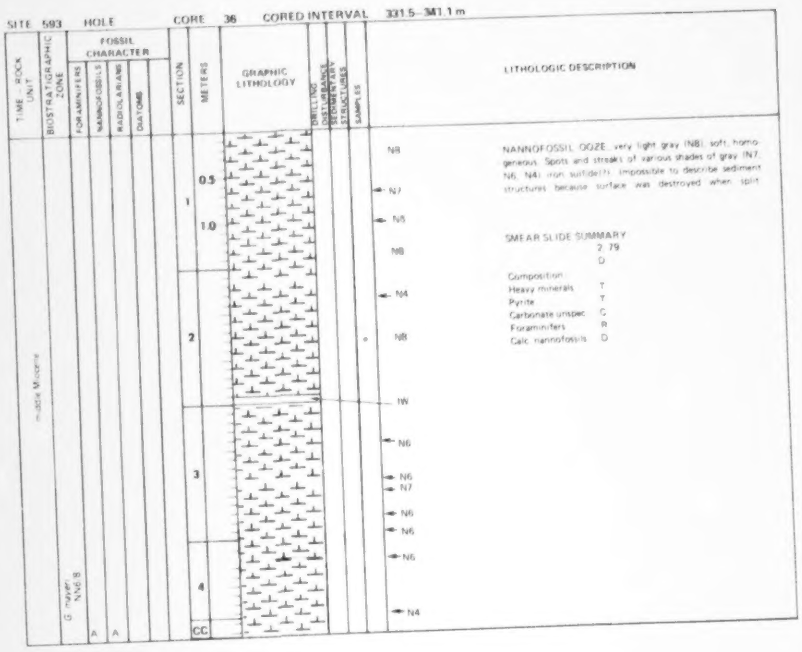

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN6-8
A
A
1
2
3
4
5
0.5
1.0
N5
N5
N5
N8
N5
Faint hues of 5GY 9/1
N5
Hues of 5GY 9/1
N5
N6
N5

NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous. A few mottles(?) and streaks of medium gray (N5) iron sulfide(?). Some zones have faint hues of very light greenish gray (5GY 9/1) but the nature of the split surface precludes any assessment of sedimentary structures.

SMEAR SLIDE SUMMARY

	3, 80
	D
Composition:	
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	A

SITE 593 HOLE CORE 36 CORED INTERVAL 331.5–341.1 m

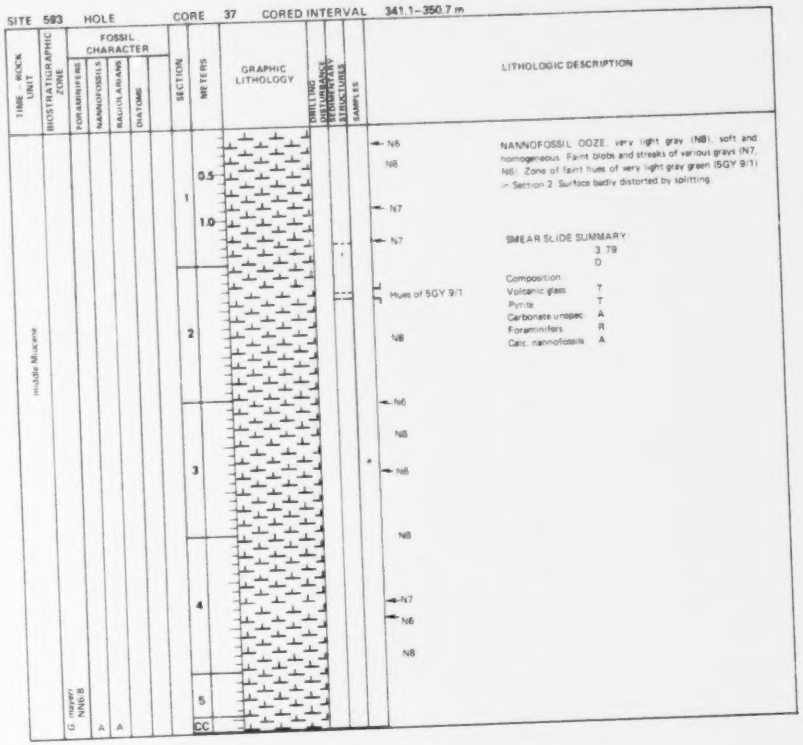

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN6/8
A
A
0.5
1.0
1
2
3
4
CC
N8
N7
N5
N8
N4
N8
IW
N6
N6
N7
N6
N6
N6
N4

NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous. Spots and streaks of various shades of gray (N7, N6, N4) iron sulfide(?). Impossible to describe sediment structures because surface was destroyed when split.

SMEAR SLIDE SUMMARY

	2, 79 D
Composition:	
Heavy minerals	T
Pyrite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 37 CORED INTERVAL 341.1–350.7 m

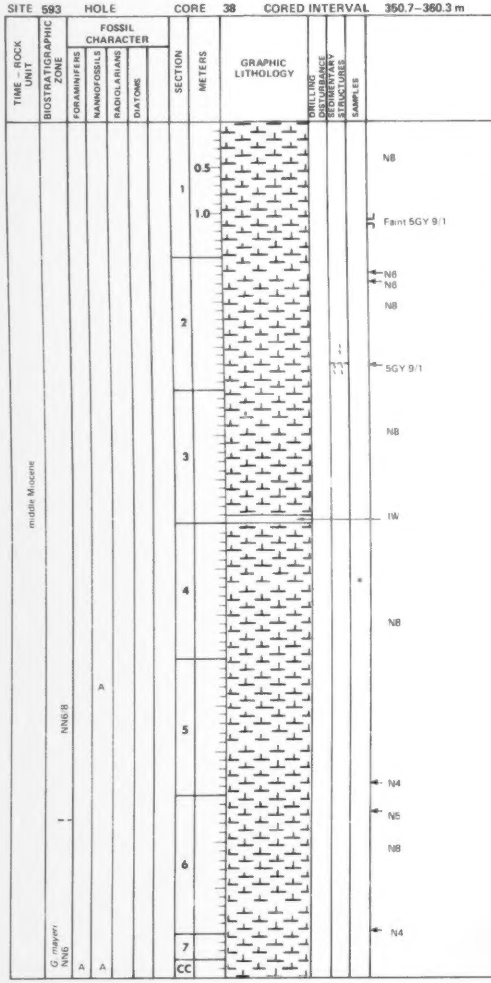

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. mayeri NN6/8
A
A
0.5
1.0
1
2
3
4
5
CC
N6
N8
N7
N7
Hues of 5GY 9/1
N8
N6
N8
N8
N8
N7
N6
N8

NANNOFOSSIL OOZE, very light gray (N8), soft and homogeneous. Faint blobs and streaks of various grays (N7, N6). Zone of faint hues of very light gray green (5GY 9/1) in Section 2. Surface badly distorted by splitting.

SMEAR SLIDE SUMMARY

	3, 79 D
Composition:	
Volcanic glass	T
Pyrite	T
Carbonate unspec.	A
Foraminifers	R
Calc. nannofossils	A

SITE 593 HOLE CORE 38 CORED INTERVAL 350.7–360.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6/8
G. mayeri
NN6
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
Faint 5GY 9/1
N6
N6
N8
5GY 9/1
N8
IW
N8
N4
N5
N8
N4

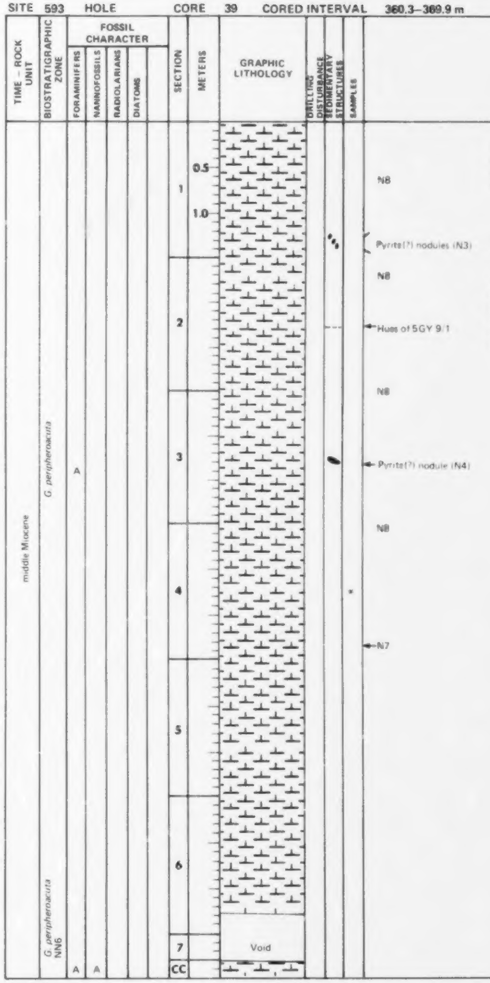
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft to stiff, homogeneous. A few zones of faint hues of 5GY 9/1 and several zones of grays (N6, N5, N4) of iron sulfides(?). Surface disrupted by splitting.

SMEAR SLIDE SUMMARY

	4, 68
	D
Composition:	
Feldspar	T
Pyrite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 39 CORED INTERVAL 360.3–369.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. peripheroacuta
G. peripheroacuta
NN6
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
Pyrite(?) nodules (N3)
N8
Hues of 5GY 9/1
N8
Pyrite(?) nodule (N4)
N8
N7

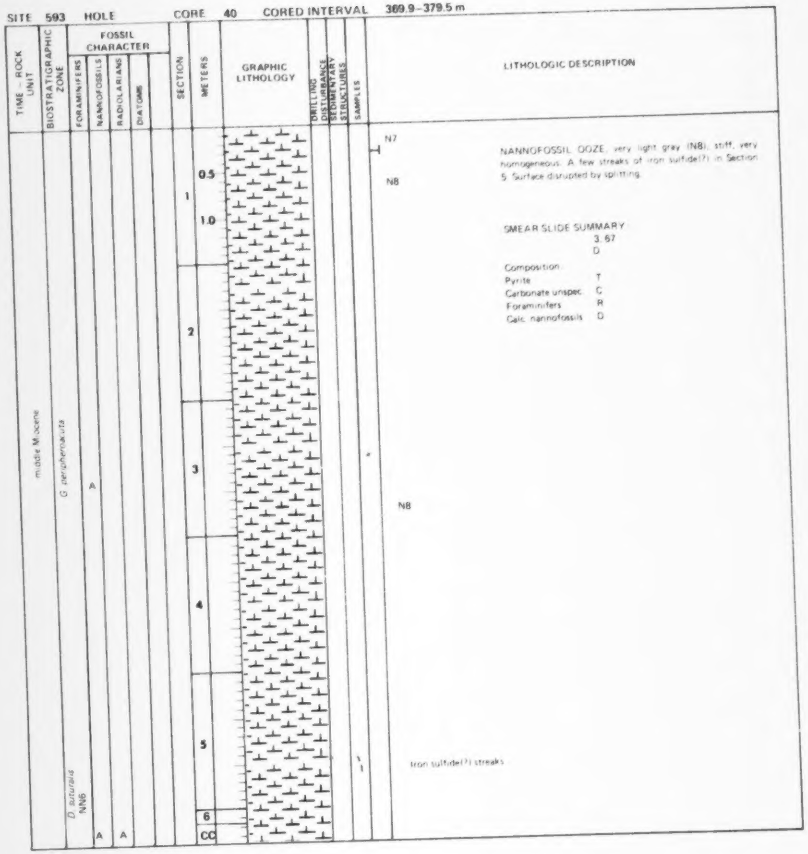
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft to firm, homogeneous. Streaks of medium gray (N4) iron sulfide(?). Nodules of pyrite(?) in Section 3, 75 cm and Section 1, 125 cm. Surface disrupted by splitting.

SMEAR SLIDE SUMMARY

	4, 60
	D
Composition:	
Volcanic glass	T
Pyrite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 40 CORED INTERVAL 369.9–379.5 m

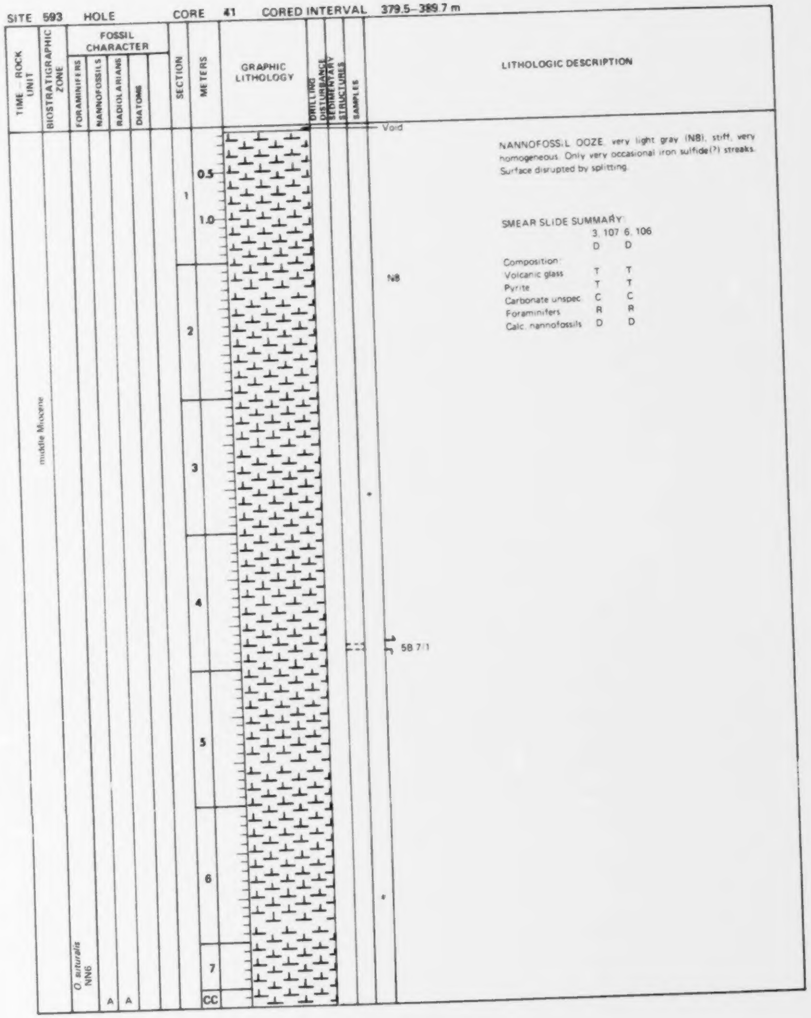

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. peripheroacuta
D. suturalis NN6
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N7
N8
N8
Iron sulfide(?) streaks

NANNOFOSSIL OOZE, very light gray (N8), stiff, very homogeneous. A few streaks of iron sulfide(?) in Section 5. Surface disrupted by splitting.

SMEAR SLIDE SUMMARY:

	3, 67 D
Composition:	
Pyrite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 41 CORED INTERVAL 379.5–389.7 m

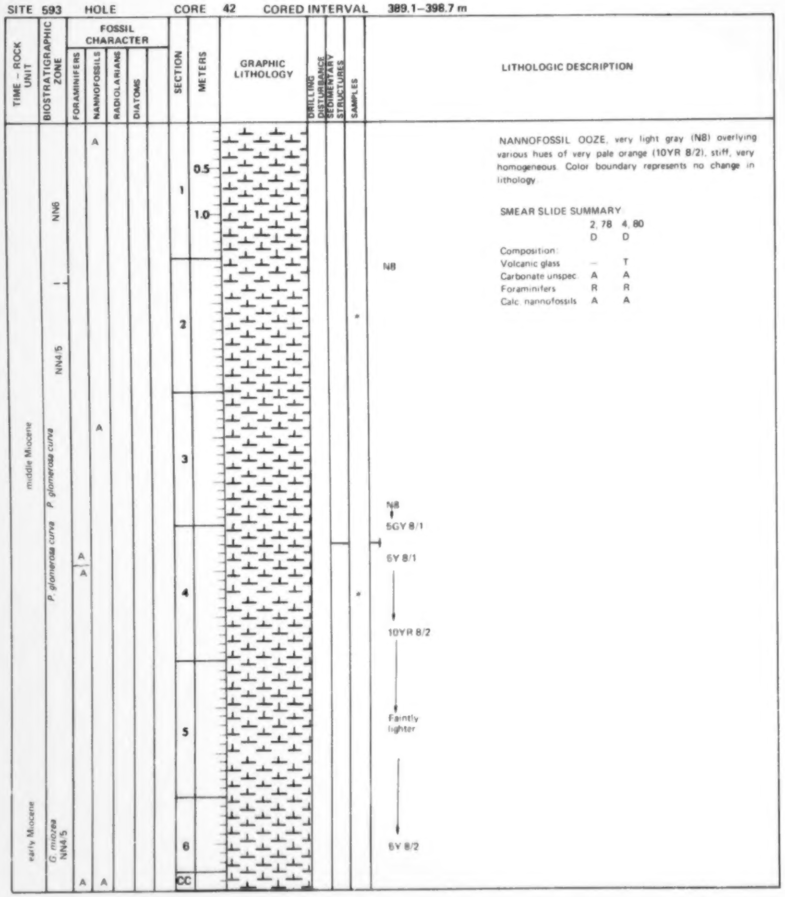

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
O. suturalis NN6
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
N8
5B 7/1

NANNOFOSSIL OOZE, very light gray (N8), stiff, very homogeneous. Only very occasional iron sulfide(?) streaks. Surface disrupted by splitting.

SMEAR SLIDE SUMMARY:

	3, 107 D	6, 106 D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Carbonate unspec.	C	C
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 593 HOLE CORE 42 CORED INTERVAL 389.1–398.7 m

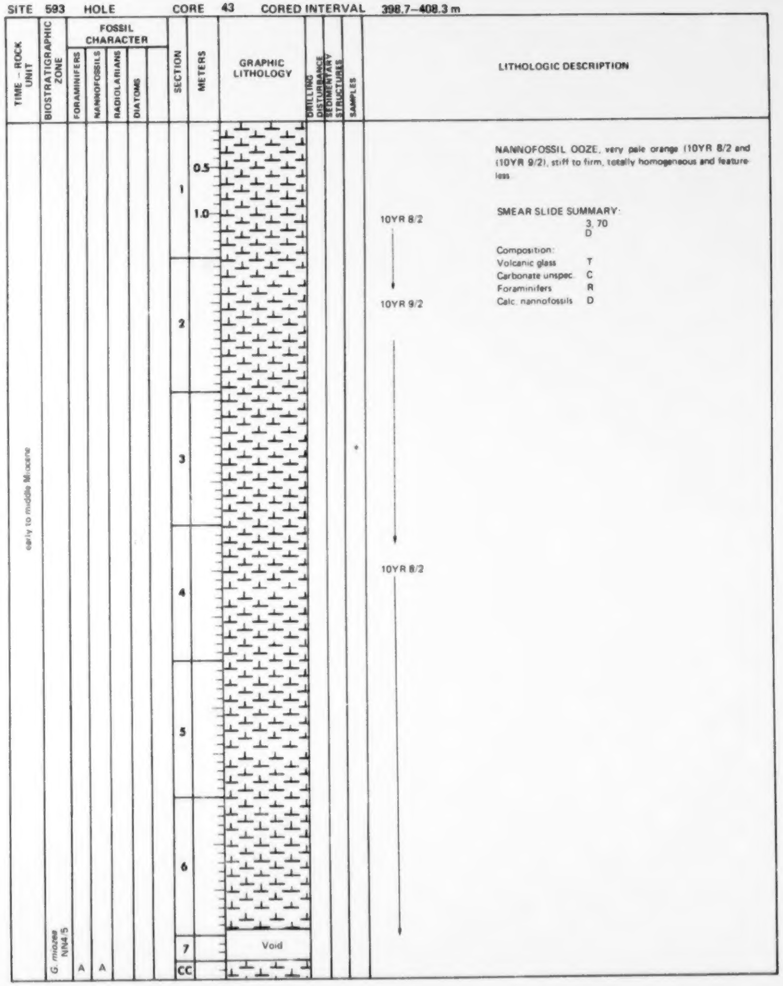

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
early Miocene
NN6
NN4/5
P. glomerosa curva
P. glomerosa curva
G. miozea
NN4/5
A
A
A
A
A
A
1
2
3
4
5
6
CC
0.5
1.0
N8
N8
5GY 8/1
6Y 8/1
10YR 8/2
Faintly lighter
5Y 8/2

NANNOFOSSIL OOZE, very light gray (N8) overlying various hues of very pale orange (10YR 8/2), stiff, very homogeneous. Color boundary represents no change in lithology.

SMEAR SLIDE SUMMARY

	2, 78	4, 80
	D	D
Composition:		
Volcanic glass	—	T
Carbonate unspec.	A	A
Foraminifers	R	R
Calc. nannofossils	A	A

SITE 593 HOLE CORE 43 CORED INTERVAL 398.7–408.3 m

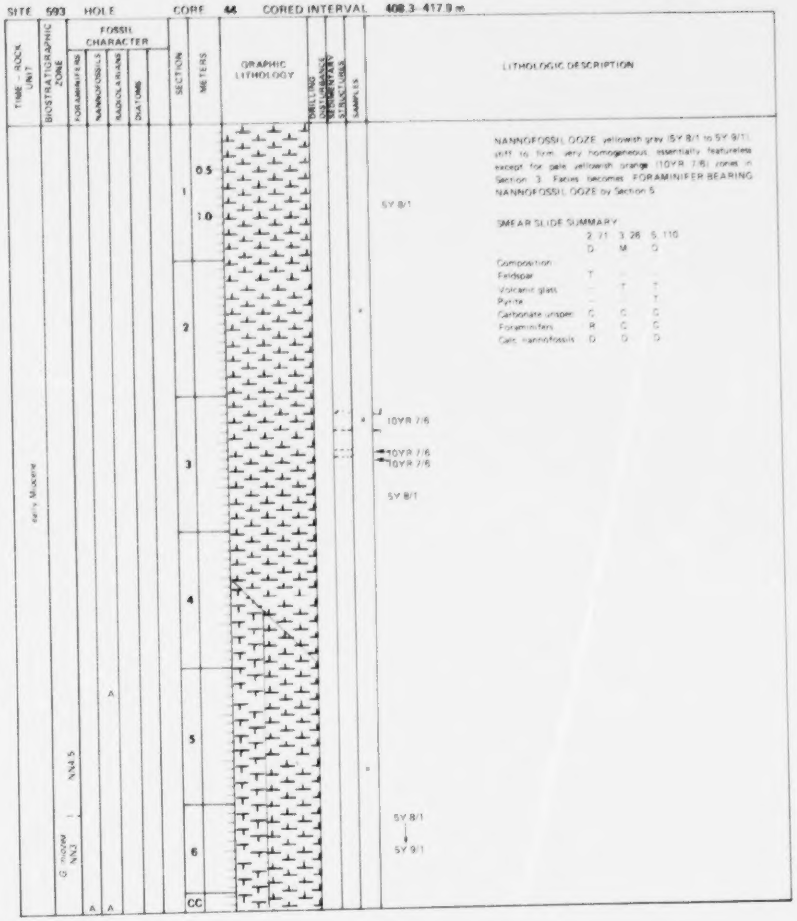

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early to middle Miocene
G. miozea
NN4/5
A
A
1
2
3
4
5
6
7
CC
0.5
1.0
Void
10YR 8/2
10YR 9/2
10YR 8/2

NANNOFOSSIL OOZE, very pale orange (10YR 8/2 and (10YR 9/2), stiff to firm, totally homogeneous and featureless.

SMEAR SLIDE SUMMARY:

	3, 70
	D
Composition:	
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 44 CORED INTERVAL 408.3–417.9 m

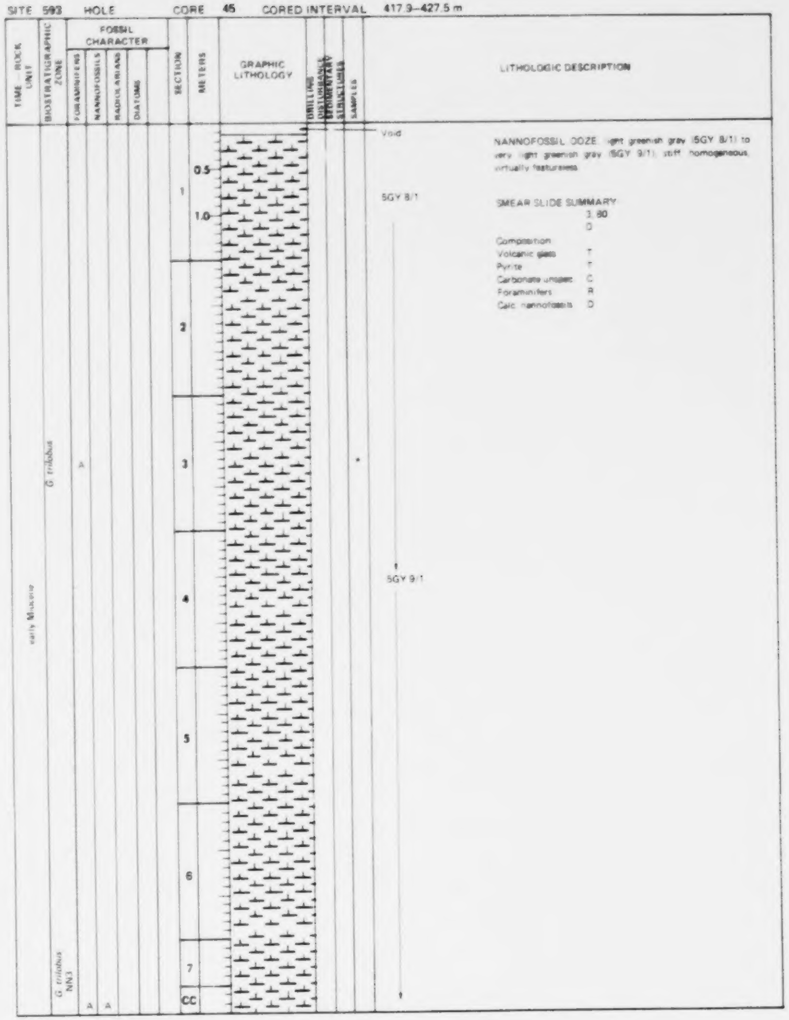

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
NN4-5
G. insueta
NN3
A
A
A
0.5
1.0
1
2
3
4
5
6
CC
5Y 8/1
10YR 7/6
10YR 7/6
10YR 7/6
5Y 8/1
5Y 8/1
5Y 9/1

NANNOFOSSIL OOZE, yellowish gray (5Y 8/1 to 5Y 9/1), stiff to firm, very homogeneous, essentially featureless except for pale yellowish orange (10YR 7/6) zones in Section 3. Facies becomes FORAMINIFER BEARING NANNOFOSSIL OOZE by Section 5.

SMEAR SLIDE SUMMARY

	2, 71	3, 26	5, 110
	D	M	D
Composition:			
Feldspar	T	–	–
Volcanic glass	–	T	T
Pyrite	–	–	T
Carbonate unspec.	C	C	C
Foraminifers	R	C	C
Calc. nannofossils	D	D	D

SITE 593 HOLE CORE 45 CORED INTERVAL 417.9–427.5 m

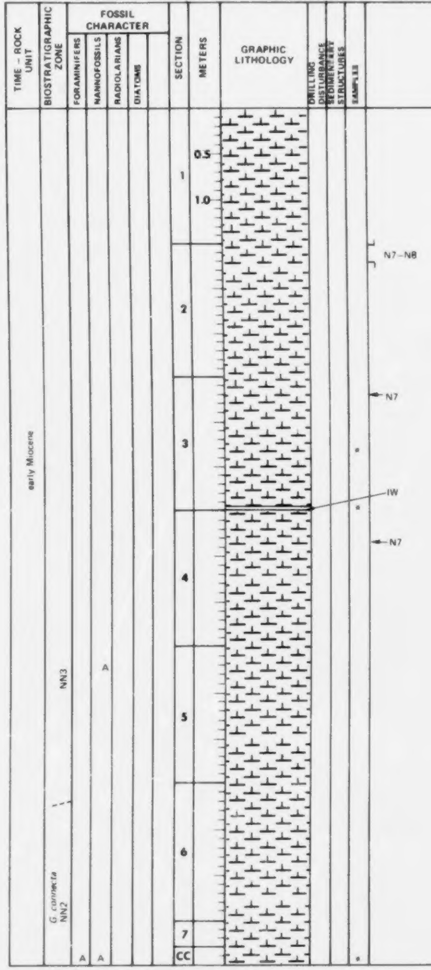

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
G. trilobus
G. trilobus
NN3
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
5GY 8/1
5GY 9/1

NANNOFOSSIL OOZE, light greenish gray (5GY 8/1) to very light greenish gray (5GY 9/1), stiff, homogeneous, virtually featureless.

SMEAR SLIDE SUMMARY

	3, 80
	D
Composition:	
Volcanic glass	T
Pyrite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 46 CORED INTERVAL 427.5–437.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN3
G. connecta NN2
A
A A
1
2
3
4
5
6
7
CC
0.5
1.0
N7–N8
N7
IW
N7

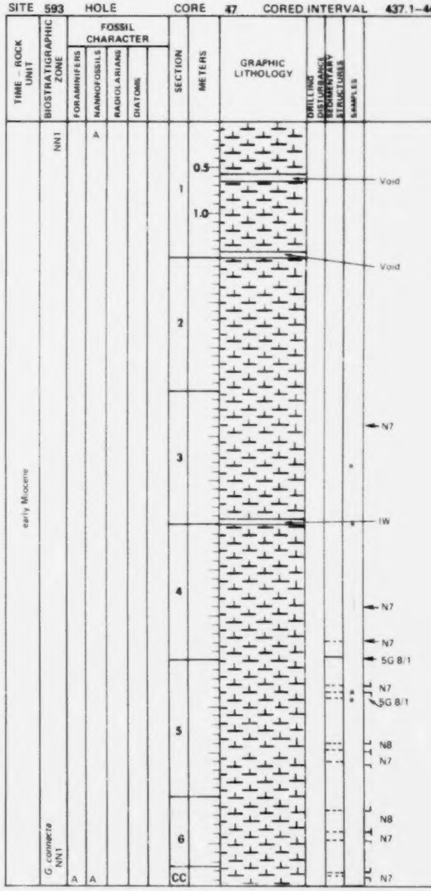
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N8–N7) level in Section 2.

SMEAR SLIDE SUMMARY

	3, 80 D	CC M
Texture:		
Sand	–	C
Silt	R	A
Clay	D	A
Composition:		
Heavy minerals	–	T
Pyrite	–	A
Carbonate unspec	C	–
Foraminifers	R	C
Calc. nannofossils	D	A

SITE 593 HOLE CORE 47 CORED INTERVAL 437.1–446.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN1
G. connecta NN1
A
A A
1
2
3
4
5
6
CC
0.5
1.0
Void
Void
N7
IW
N7
N7
5G 8/1
N7
5G 8/1
N8
N7
N8
N7
N7

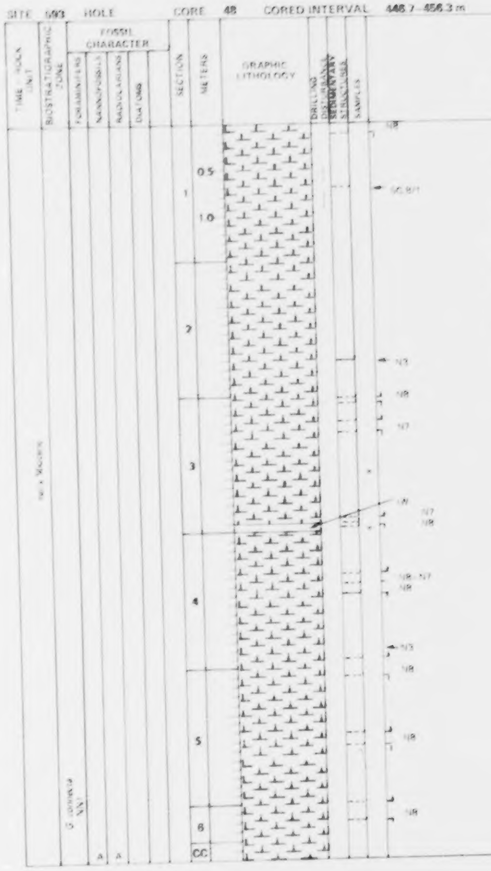
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N7–N8) zones in Sections 5, 6, and CC. Discrete light greenish gray (5G 8/1) laminae in Sections 4 and 5. Voids in Section 1 are due to drilling and core handling.

SMEAR SLIDE SUMMARY

	3, 80 D	5, 36 M	5, 39 M
Texture:			
Silt	R	R	R
Clay	D	D	D
Composition:			
Feldspar	–	T	–
Heavy minerals	T	–	–
Volcanic glass	T	T	T
Pyrite	–	–	T
Carbonate unspec	C	C	C
Foraminifers	R	R	R
Calc. nannofossils	D	D	D

SITE 593 HOLE CORE 48 CORED INTERVAL 446.7–456.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
D. druggii NN1
A
A
1
0.5
1.0
2
3
4
5
6
CC
N8
5G 8/1
N3
N8
N7
IW
N7
N8
N8–N7
N8
N3
N8
N8
N8

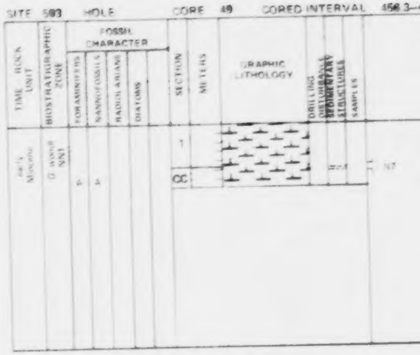
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N7) to very light gray (N8) and dark gray (N3) levels of iron sulfide(?) are present.

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture:	
Silt	T
Clay	D
Composition:	
Heavy minerals	T
Volcanic glass	T
Pyrite	T
Carbonate unspec.	C
Foraminifers	T/R
Calc. nannofossils	D

SITE 593 HOLE CORE 49 CORED INTERVAL 456.3–465.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
D. druggii NN1
A
A
1
CC
N7

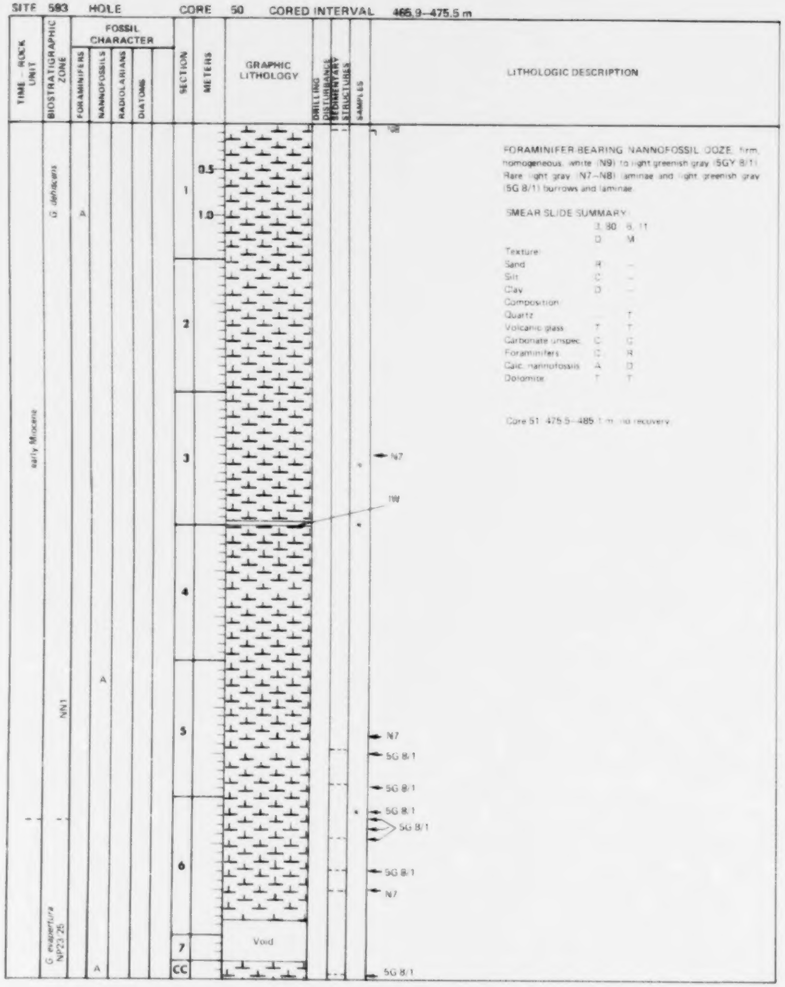
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N7) level in Core Catcher.

SMEAR SLIDE SUMMARY

	1, 30
	D
Texture:	
Sand	R
Silt	D
Composition:	
Carbonate unspec.	C
Foraminifers	R/C
Calc. nannofossils	D

SITE 593 HOLE CORE 50 CORED INTERVAL 465.9–475.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Miocene
G. dehiscens
NN1
G. evapertura NP23/25
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N8
N7
IW
N7
5G 8/1
5G 8/1
5G 8/1
5G 8/1
5G 8/1
N7
5G 8/1

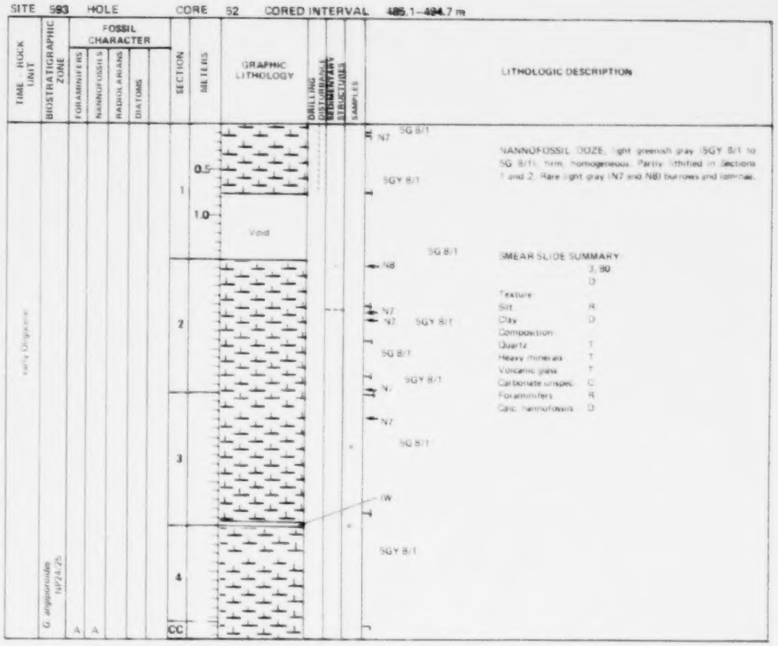
FORAMINIFER-BEARING NANNOFOSSIL OOZE, firm, homogeneous, white (N9) to light greenish gray (5GY 8/1). Rare light gray (N7–N8) laminae and light greenish gray (5G 8/1) burrows and laminae.

SMEAR SLIDE SUMMARY:

	3, 80	6, 11
	D	M
Texture:		
Sand	R	–
Silt	C	–
Clay	D	–
Composition:		
Quartz	–	T
Volcanic glass	T	T
Carbonate unspec.	C	C
Foraminifers	C	R
Calc. nannofossils	A	D
Dolomite	T	T

Core 51: 475.5–485.1 m; no recovery.

SITE 593 HOLE CORE 52 CORED INTERVAL 485.1–494.7 m

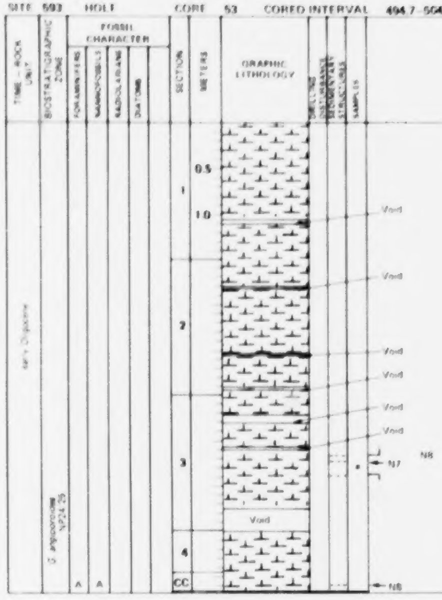

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Oligocene
G. angiporoides NP24/25
A
A
0.5
1.0
1
2
3
4
CC
Void
N7
5G 8/1
5GY 8/1
5G 8/1
N8
N7
N7
5GY 8/1
5G 8/1
5GY 8/1
N7
N7
5G 8/1
IW
5GY 8/1

NANNOFOSSIL OOZE, light greenish gray (5GY 8/1 to 5G 8/1), firm, homogeneous. Partly lithified in Sections 1 and 2. Rare light gray (N7 and N8) burrows and laminae.

SMEAR SLIDE SUMMARY:

	3, 80
	D
Texture:	
Silt	R
Clay	D
Composition:	
Quartz	T
Heavy minerals	T
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 53 CORED INTERVAL 494.7–504.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
G. angiporoides NP24-25
A
A
1
2
3
4
CC
0.5
1.0
Void
Void
Void
Void
Void
Void
Void
N7
N8
N8

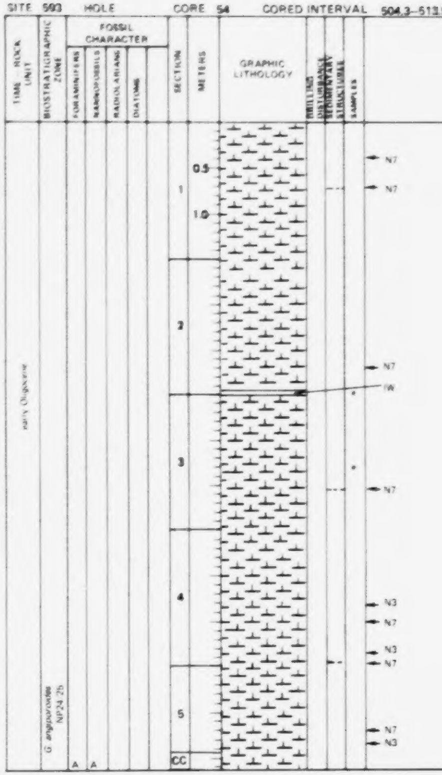
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9), firm, homogeneous. Very light gray (N8) level in Section 3. Rare light gray (N7) laminae. Voids are due to drilling and core handling.

SMEAR SLIDE SUMMARY

	3, 80
	D
Texture:	
Silt	T
Clay	D
Composition:	
Quartz	T
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	T/R
Calc. nannofossils	D
Dolomite	T

SITE 593 HOLE CORE 54 CORED INTERVAL 504.3–513.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
G. angiporoides NP24-25
A
A
1
2
3
4
5
CC
0.5
1.0
N7
N7
N7
IW
N7
N3
N7
N3
N7
N7
N3

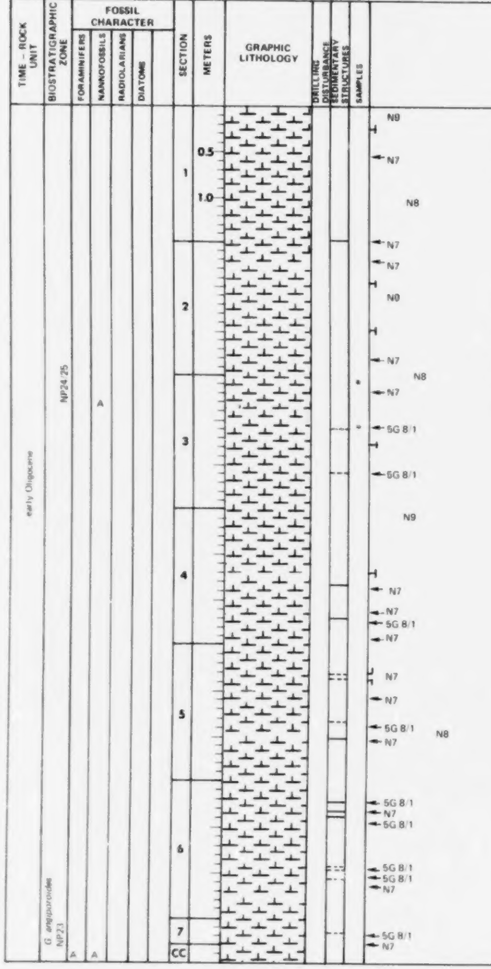
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Rare light gray (N7) and dark gray (N3) laminae.

SMEAR SLIDE SUMMARY

	3, 90
	D
Texture:	
Silt	R
Clay	D
Composition:	
Volcanic glass	T
Glauconite	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D

SITE 593 HOLE CORE 55 CORED INTERVAL 513.9–523.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP24/25
G. angiporoides
NP23
A
0.5
1.0
1
2
3
4
5
6
7
CC
N9
N7
N8
N7
N7
N9
N7
N8
N7
5G 8/1
5G 8/1
N9
N7
N7
5G 8/1
N7
N7
N7
5G 8/1
N7
N8
5G 8/1
N7
5G 8/1
5G 8/1
5G 8/1
N7
5G 8/1
N7

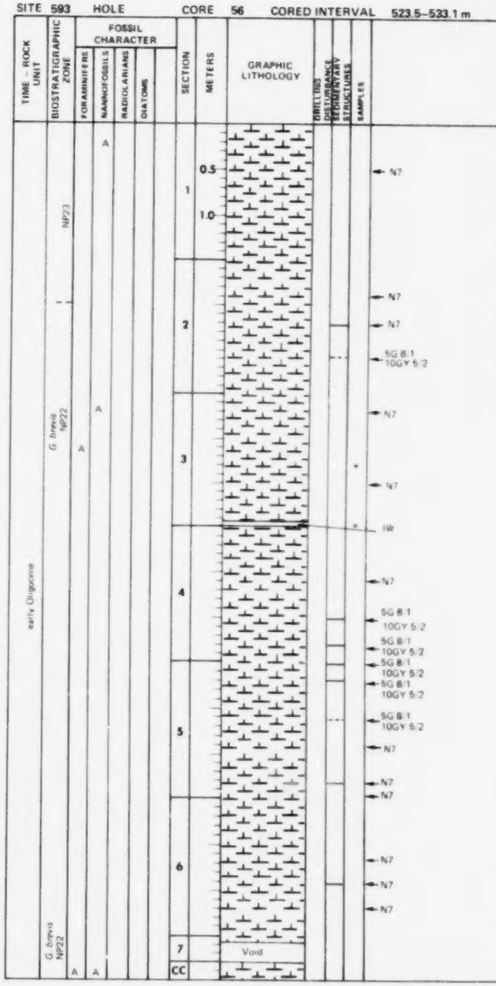
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N7) laminae of iron sulfide(?). Discrete light greenish gray (5G 8/1) laminae below Section 2.

SMEAR SLIDE SUMMARY

	3, 80 D	3, 56 M
Texture		
Silt	R	R
Clay	D	D
Composition:		
Quartz	–	T
Heavy minerals	–	T
Volcanic glass	T	T
Carbonate unspec	C	C
Foraminifers	R	R
Calc. nannofossils	D	D
Dolomite	–	T

SITE 593 HOLE CORE 56 CORED INTERVAL 523.5–533.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP23
G. brevis
NP22
G. brevis
NP22
A
0.5
1.0
1
2
3
4
5
6
7
CC
Void
N7
N7
N7
5G 8/1
10GY 5/2
N7
N7
IW
N7
5G 8/1
10GY 5/2
5G 8/1
10GY 5/2
5G 8/1
10GY 5/2
5G 8/1
10GY 5/2
5G 8/1
10GY 5/2
N7
N7
N7
N7
N7
N7

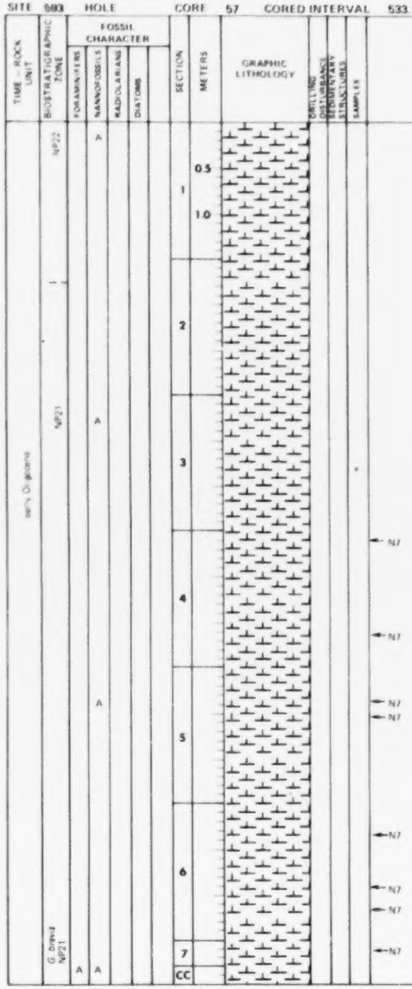
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8) to light greenish gray (5GY 8/1), homogeneous, with alternations of firm and stiff sediments. Light gray (N7) burrows and light gray (N7), light greenish gray (5G 8/1) to grayish green (10GY 5/2) laminae common.

SMEAR SLIDE SUMMARY

	3, 80 D
Composition:	
Quartz	T
Heavy minerals	T
Carbonate unspec	C
Foraminifers	T/R
Calc. nannofossils	D
Dolomite	T

SITE 593 HOLE CORE 57 CORED INTERVAL 533.1–542.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP22
NP21
G. brevis NP21
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N7
N7
N7
N7
N7
N7
N7
N7

LITHOLOGIC DESCRIPTION

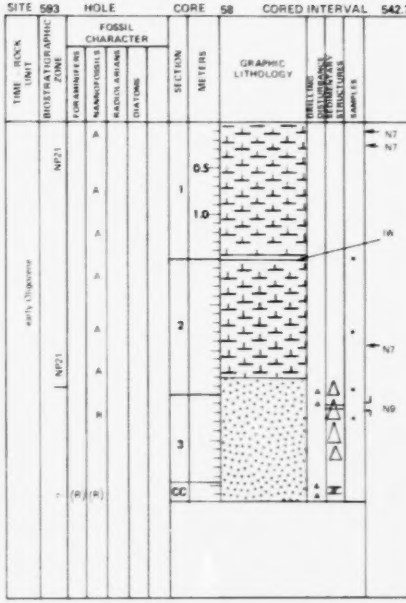
NANNOFOSSIL OOZE, homogeneous, with alternations of firm and stiff sediments. White (N9) to very light gray (N8).

Rare light gray (N7) burrows and laminae.

SMEAR SLIDE SUMMARY

	3, 80 D
Texture	
Silt	R
Clay	D
Composition	
Quartz	T
Heavy minerals	T
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	R
Calc. nannofossils	D
Dolomite	T

SITE 593 HOLE CORE 58 CORED INTERVAL 542.7–552.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Oligocene
NP21
NP21
A
A
A
A
A
A
R
(R) (R)
0.5
1.0
1
2
3
CC
N7
N7
IW
N7
N9

LITHOLOGIC DESCRIPTION

Section 1, 0 cm through Section 2, 130 cm: NANNOFOSSIL OOZE, white (N9) to very light gray (N8), homogeneous, with alternations of firm and stiff sediment. Rare light gray (N7) laminae in Section 1 through Section 2, 129 cm.

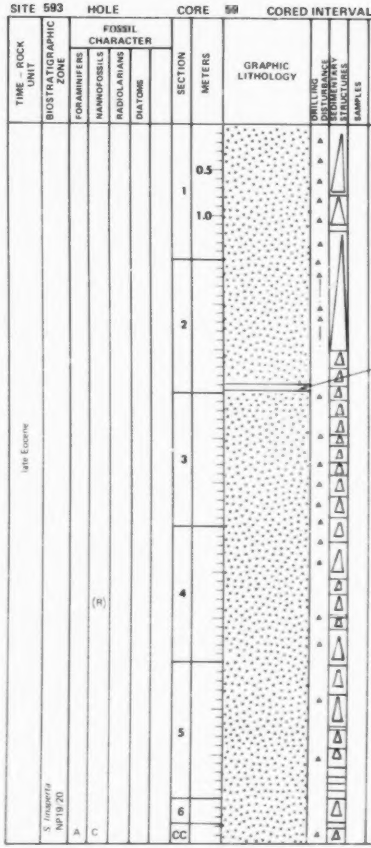
Section 2, 130 cm through Core Catcher: LITHIFIED VOLCANOGENIC TURBIDITES, grayish olive green (5GY 3/2) to dusky yellowish green (10GY 3/2) until 25 cm Section 3 then grayish olive green (5GY 3/2) to dark gray (N4). White (N9) veins of calcite are present. White (N9) laminae of nannofossil chalk in Section 3. Sediment generally normally graded. Cross-beddings are present in Core Catcher.

Cross-beddings are present in Core Catcher.

SMEAR SLIDE SUMMARY

	2, 80 D	2, 140 D	3, 26 M
Composition			
Quartz	–	T	–
Feldspar	–	T	–
Heavy minerals	–	T	–
Clay	–	A	–
Volcanic glass	T	T	T
Glauconite	–	C	–
Carbonate unspec.	C	C	D
Foraminifers	R	R	R
Calc. nannofossils	C	C	R
Other	T	–	–

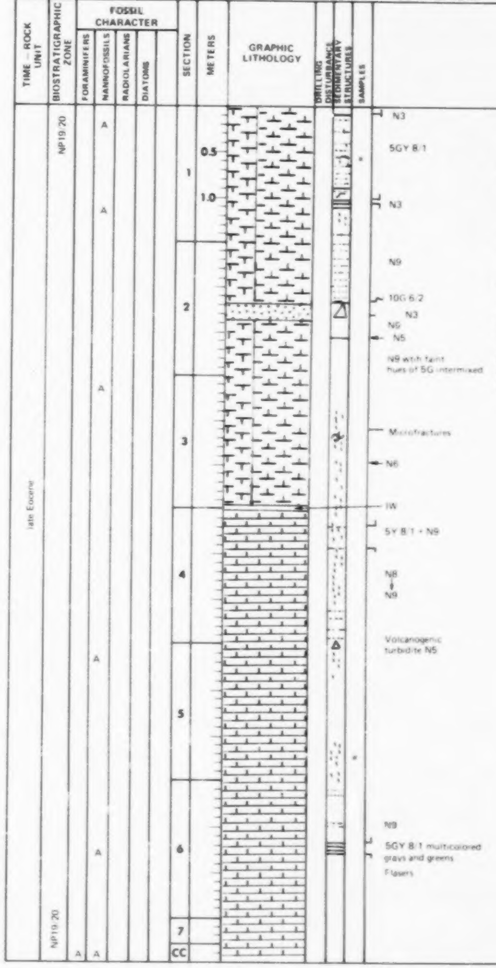
SITE 593 HOLE CORE 59 CORED INTERVAL 552.3–561.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
S. linaperta
NP19/20
A
C
(R)
0.5
1.0
1
2
3
4
5
6
CC
IW

LITHOLOGIC DESCRIPTION

LITHIFIED VOLCANOGENIC TURBIDITES, predominantly grayish black (N2) with some grayish green (5GY) hues in coarser lithologies, hard (lithified), repetitive packets of upward-fining units involving breccia to sandstone to siltstone or sandstone to siltstone, several with Bouma sedimentary structure sequences (especially A, B, and E divisions). Siltstones are glassy (cf. obsidian) and detritus possibly of glassy rhyolite composition. Occasional calcite veining. Core retains stratigraphic entity, but all sections include brecciated material due to coring, and some biscuit structures.

SITE 593 HOLE CORE 60 CORED INTERVAL 561.9–571.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Eocene
NP19/20
NP19/20
A
A
A
A
A
A
A
A
0.5
1.0
1
2
3
4
5
6
7
CC
N3
5GY 8/1
N3
N9
10G 6/2
N3
N6
N5
N9 with faint hues of 5G intermixed
Microfractures
N6
IW
5Y 8/1 + N9
N8
N9
Volcanogenic turbidite N5
N9
5GY 8/1 multicolored grays and greens
Flasers

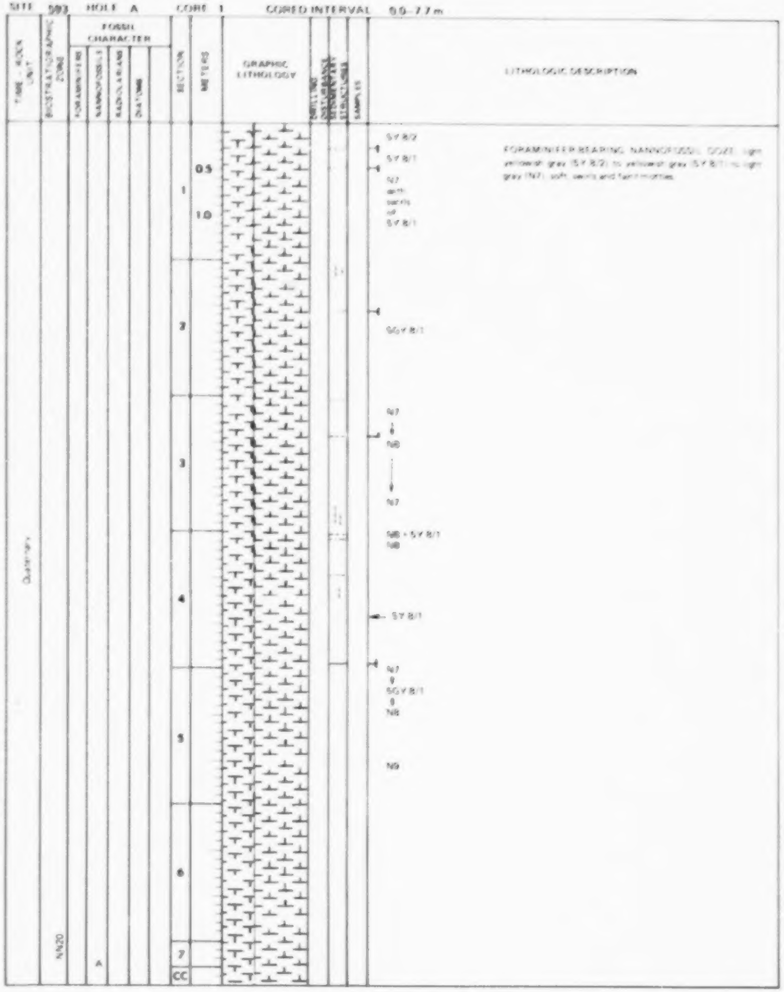
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL CHALK grading with depth to NANNOFOSSIL CHALK, light greenish gray (5GY 8/1) to white (N9), varies from stiff to hard (ooze to chalk), intensely burrowed. Numerous thin very pale green (10G 8/1) volcanic ash layers (indicated by *****) in sedimentary structures column. Flaser-like beds common and *Zoophycus* burrows numerous. *Planolites* common. Volcanogenic turbidite, lithified at Section 2, 57 to 78 cm. Chalk below this turbidite is almost featureless. Microfractures in Section 3. Volcanogenic turbidite in bottom Section 4.

SMEAR SLIDE SUMMARY

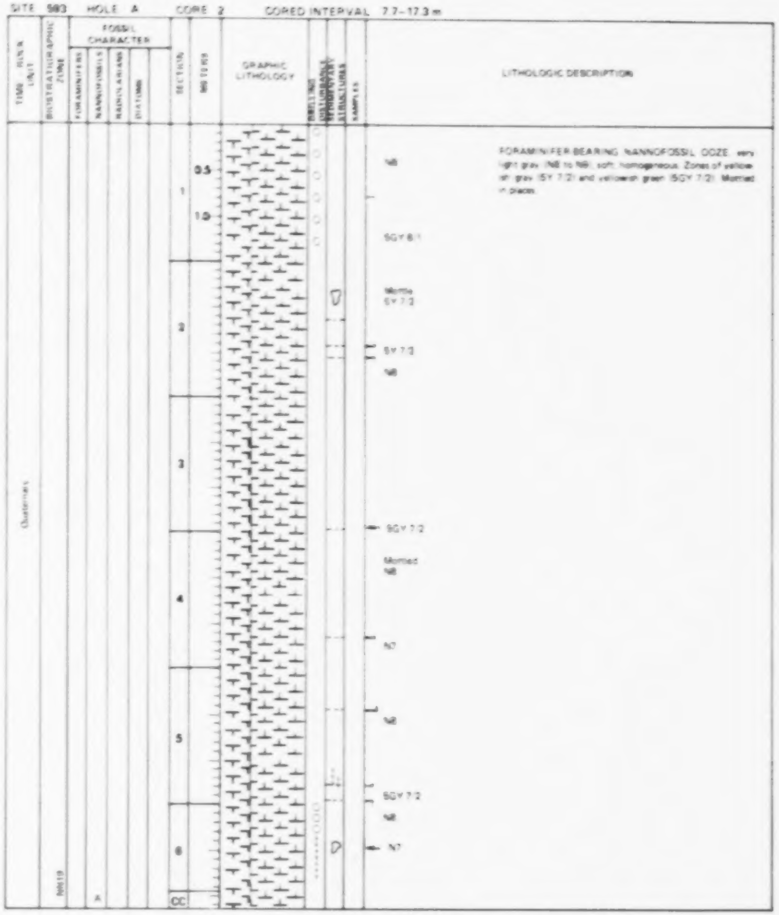
	1, 60	5, 120
	D	D
Composition:		
Feldspar	—	T
Volcanic glass	T	T
Carbonate unspec.	C	A
Foraminifers	C	R
Calc. nannofossils	A	A

SITE 593 HOLE A CORE 1 CORED INTERVAL 0.0–7.7 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN20
A
1
2
3
4
5
6
7
CC
0.5
1.0
5Y 8/2
5Y 8/1
N7 with swirls of 5Y 8/1
5GY 8/1
N7
N8
N7
N8 + 5Y 8/1
N8
5Y 8/1
N7
5GY 8/1
N8
N9

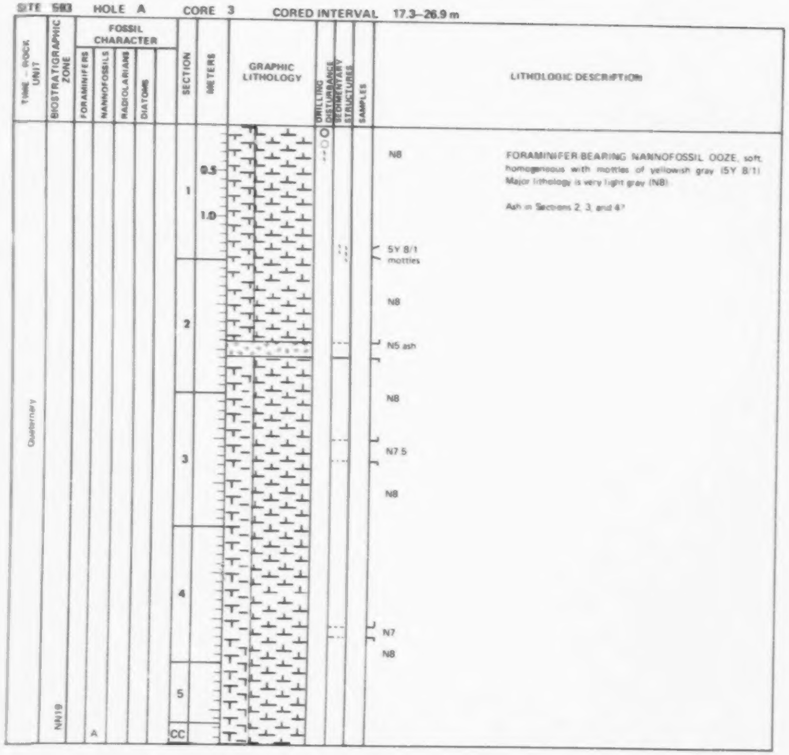
FORAMINIFER-BEARING NANNOFOSSIL OOZE, light yellowish gray (5Y 8/2) to yellowish gray (5Y 8/1) to light gray (N7), soft, swirls and faint mottles.

SITE 593 HOLE A CORE 2 CORED INTERVAL 7.7–17.3 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19
A
1
2
3
4
5
6
CC
0.5
1.0
N8
5GY 8/1
Mottle 5Y 7/2
5Y 7/2
N8
5GY 7/2
Mottled N8
N7
N8
5GY 7/2
N8
N7

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8 to N9), soft, homogeneous. Zones of yellowish gray (5Y 7/2) and yellowish green (5GY 7/2). Mottled in places.

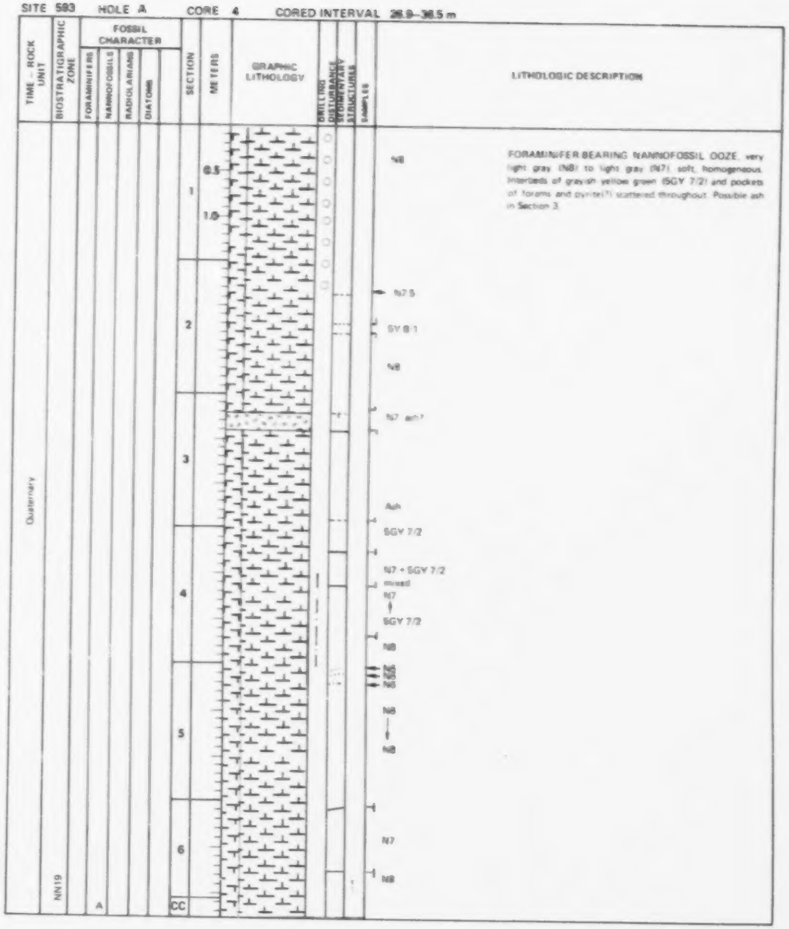
SITE 593 HOLE A CORE 3 CORED INTERVAL 17.3–26.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19
A
1
2
3
4
5
CC
0.5
1.0
N8
5Y 8/1 mottles
N8
N5 ash
N8
N7.5
N8
N7
N8

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, homogeneous with mottles of yellowish gray (5Y 8/1). Major lithology is very light gray (N8).

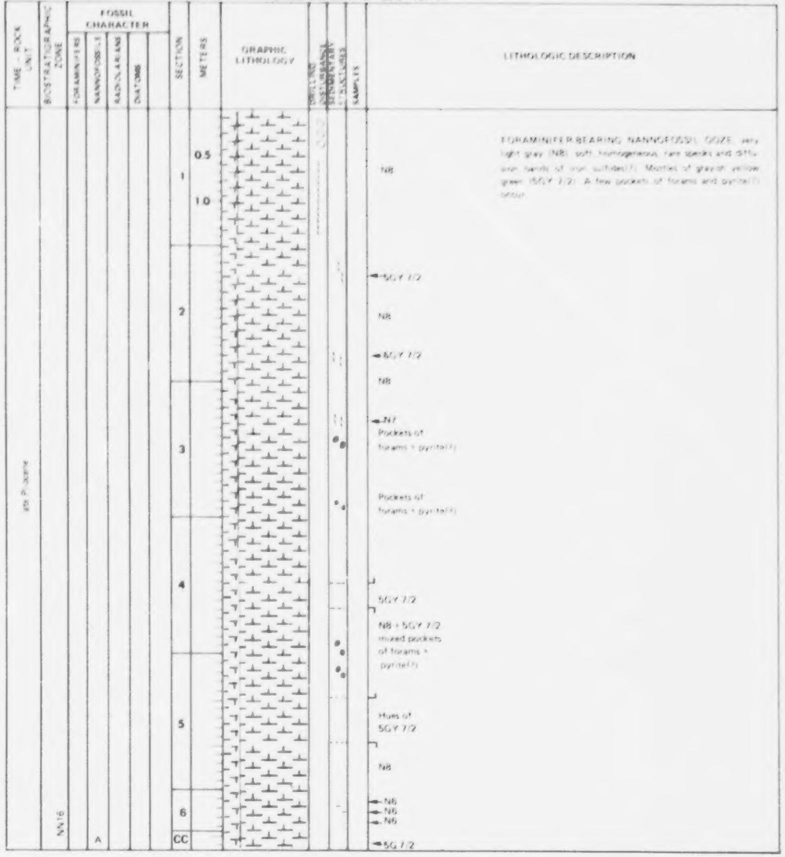
Ash in Sections 2, 3, and 4?

SITE 593 HOLE A CORE 4 CORED INTERVAL 26.9–36.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
Quaternary
NN19
A
1
2
3
4
5
6
CC
0.5
1.0
N8
N7.5
5Y 8/1
N8
N7 ash?
Ash
5GY 7/2
N7 + 5GY 7/2 mixed
N7
5GY 7/2
N8
N5
N5
N5
N6
N8
N7
N8

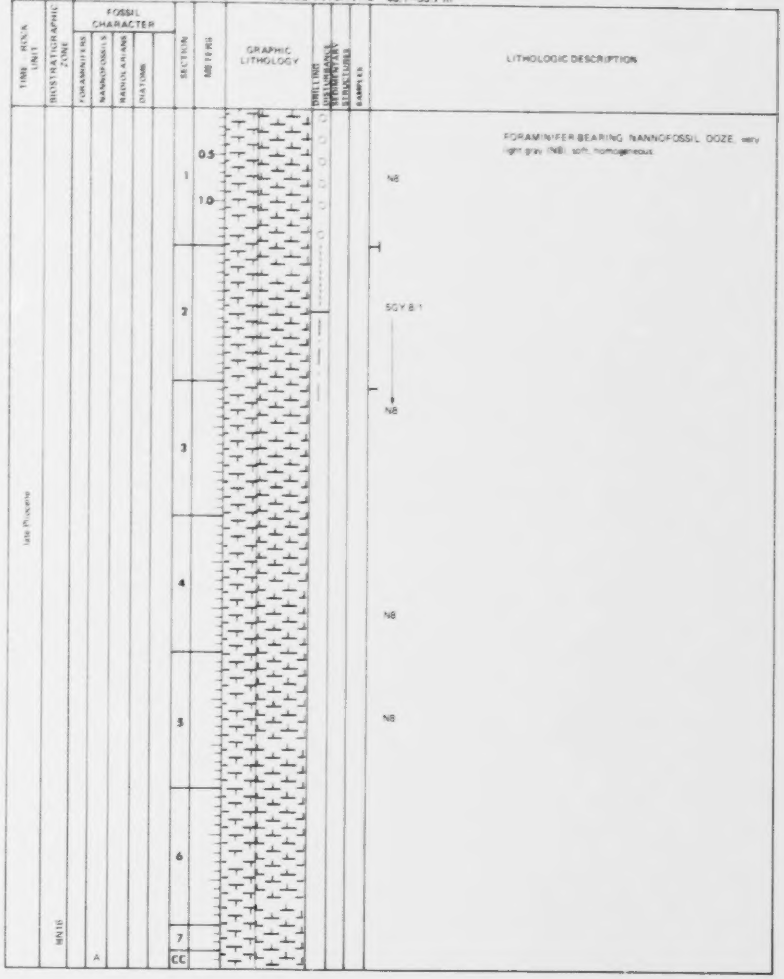
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7), soft, homogeneous. Interbeds of grayish yellow green (5GY 7/2) and pockets of forams and pyrite(?) scattered throughout. Possible ash in Section 3.

SITE 593 HOLE A CORE 5 CORED INTERVAL 36.5–46.1 m

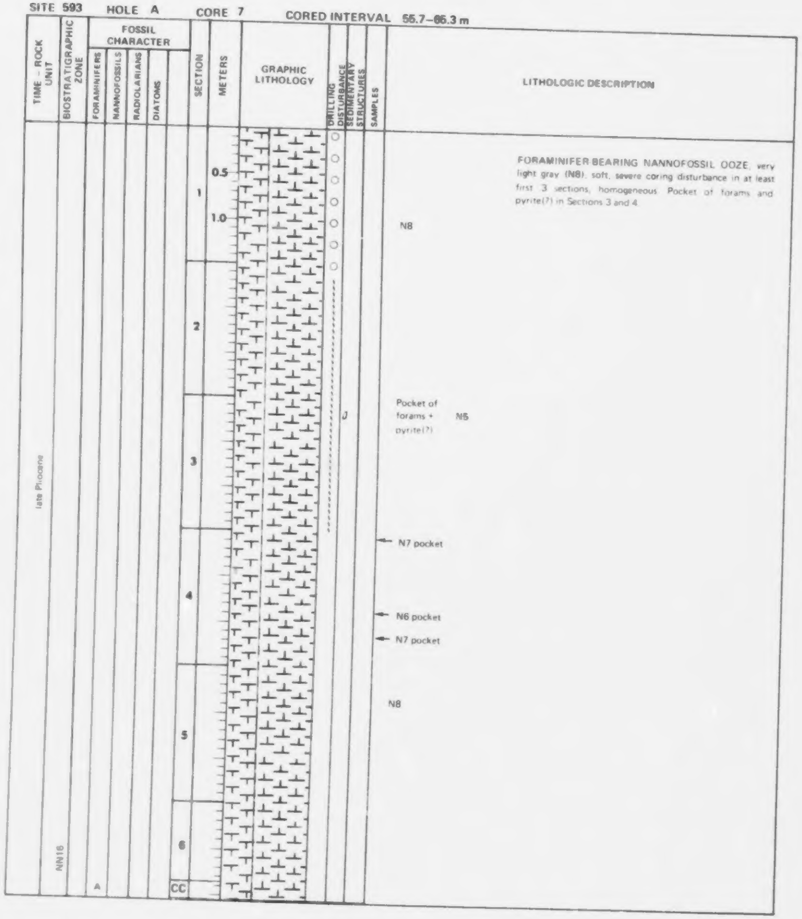

TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
NN16
A
0.5
1.0
1
2
3
4
5
6
CC
N8
5GY 7/2
N8
5GY 7/2
N8
N7
Pockets of forams + pyrite(?)
Pockets of forams + pyrite(?)
5GY 7/2
N8 + 5GY 7/2 mixed pockets of forams + pyrite(?)
Hues of 5GY 7/2
N8
N6
N6
N6
5G 7/2

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, rare specks and diffuse bands of iron sulfides(?). Mottles of grayish yellow green (5GY 7/2). A few pockets of forams and pyrite(?) occur.

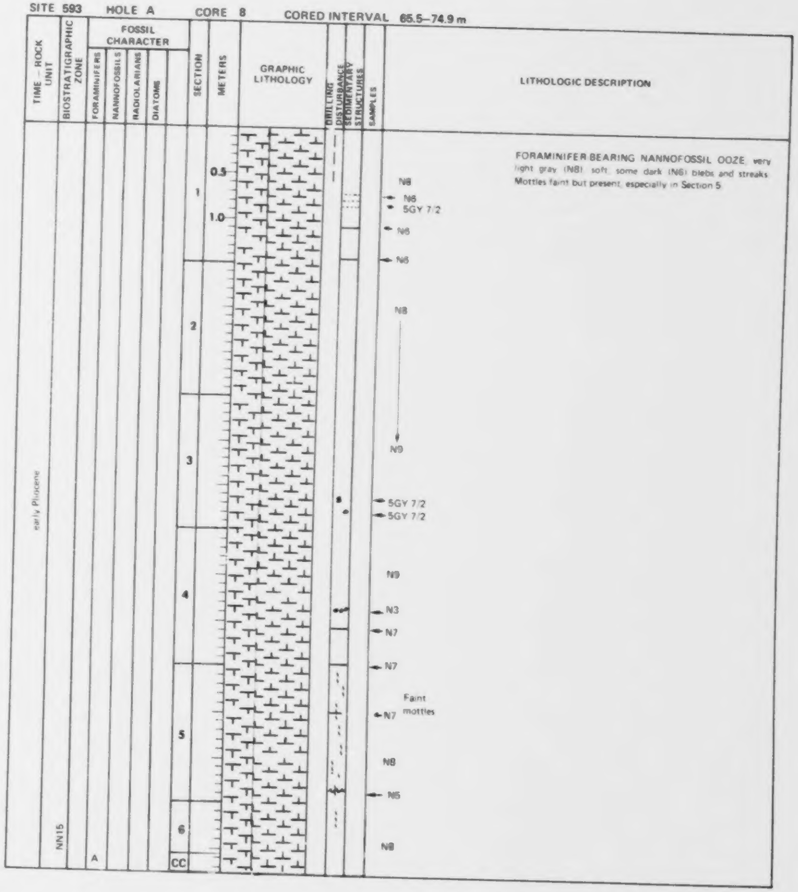
SITE 593 HOLE A CORE 6 CORED INTERVAL 46.1–55.7 m


TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
NN16
A
0.5
1.0
1
2
3
4
5
6
7
CC
N8
5GY 8/1
N8
N8
N8

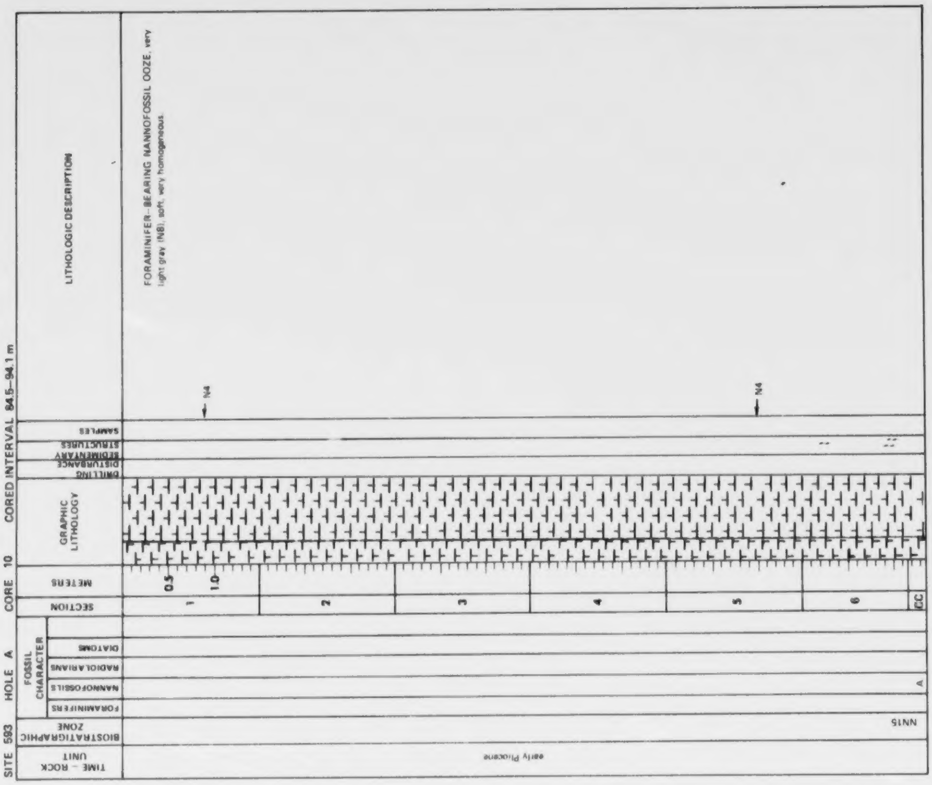
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous.


SITE 593
HOLE A
CORE 7
CORED INTERVAL 55.7–66.3 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Pliocene
NN16
A
1
2
3
4
5
6
CC
0.5
1.0
N8
Pocket of forams + pyrite(?)
N5
N7 pocket
N6 pocket
N7 pocket
N8

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, severe coring disturbance in at least first 3 sections, homogeneous. Pocket of forams and pyrite(?) in Sections 3 and 4.


SITE 593
HOLE A
CORE 8
CORED INTERVAL 65.5–74.9 m
TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
A
1
2
3
4
5
6
CC
0.5
1.0
N8
N6
5GY 7/2
N6
N5
N8
N9
5GY 7/2
5GY 7/2
N9
N3
N7
N7
Faint mottles
N7
N8
N5
N8

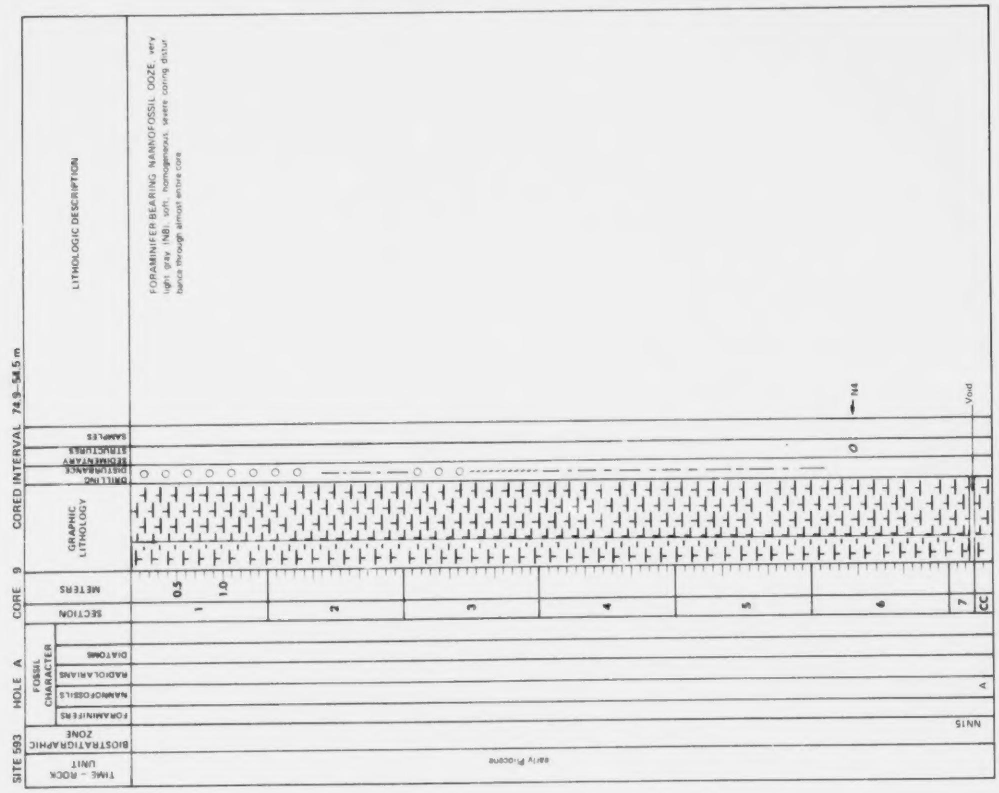
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, some dark (N6) blebs and streaks. Mottles faint but present, especially in Section 5.



SITE 593 HOLE A CORE 10 CORED INTERVAL 84.5–94.1 m

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
CC
N4
N4

FORAMINIFER–BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous.

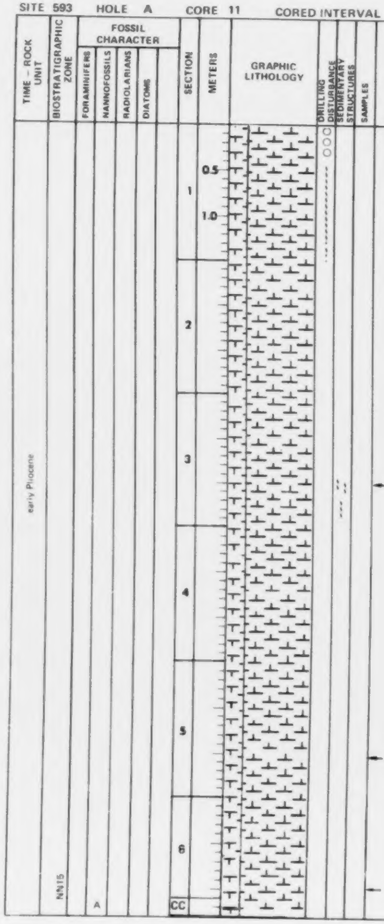


SITE 593 HOLE A CORE 9 CORED INTERVAL 74.9–84.5 m

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
early Pliocene
NN15
A
0.5
1.0
1
2
3
4
5
6
7
CC
N4
Void

FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, severe coring disturbance through almost entire core

SITE 593 HOLE A CORE 11 CORED INTERVAL 94.1–103.7 m

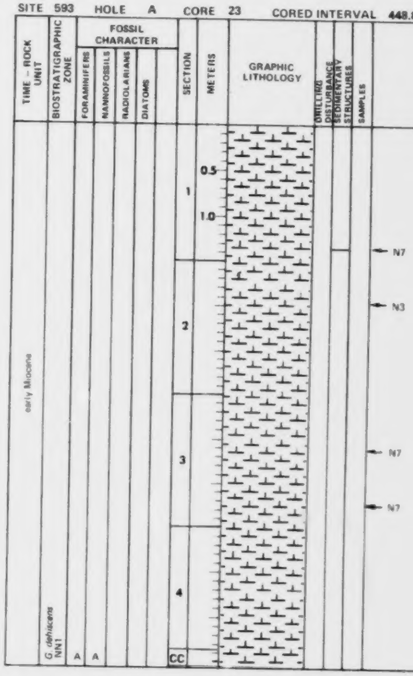

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN15
A
1
2
3
4
5
6
CC
0.5
1.0
N6
5GY 7/2
N4

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous with only very rare iron sulfide(?) diffusion bands and pockets of grayish yellow green (5GY 7/2).

NOTE 593A. Cores 12 through 22 have not been split – no core barrel sheets.

SITE 593 HOLE A CORE 23 CORED INTERVAL 448.8–458.4 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. dehiscens
NN1
A
A
1
2
3
4
CC
0.5
1.0
N7
N3
N7
N7

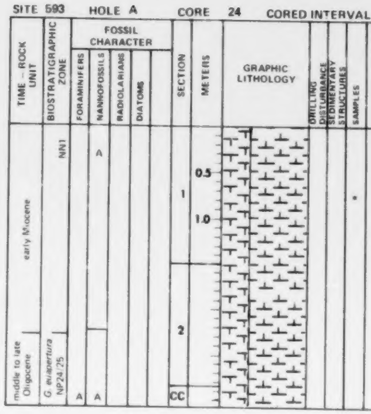
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous. Rare light gray (N7) and dark gray (N3) laminae.

SMEAR SLIDE SUMMARY

	2, 80
	D
Texture:	
Silt	R
Clay	D
Composition:	
Quartz	T
Mica	T
Volcanic glass	T
Carbonate unspec	T
Foraminifers	T
Calc. nannofossils	D

SITE 593 HOLE A CORE 24 CORED INTERVAL 458.4–468.0 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
NN1
A
middle to late Oligocene
G. euapertura
NP24/25
A
A
1
2
CC
0.5
1.0
*

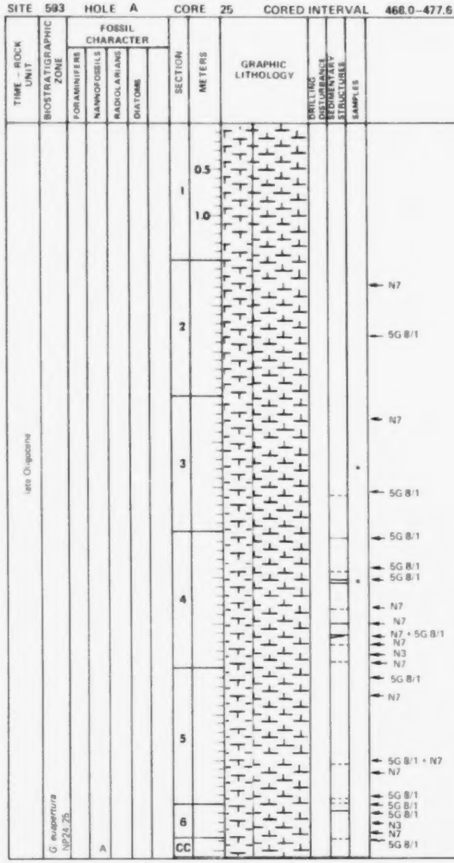
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous.

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Heavy minerals	T
Pyrite	T
Carbonate unspec	R
Foraminifers	C
Calc. nannofossils	D

SITE 593 HOLE A CORE 25 CORED INTERVAL 468.0–477.6 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
G. euapertura
NP24.25
A
1
2
3
4
5
6
CC
0.5
1.0
N7
5G 8/1
N7
5G 8/1
5G 8/1
5G 8/1
5G 8/1
N7
N7
N7 + 5G 8/1
N7
N3
N7
5G 8/1
N7
5G 8/1 + N7
N7
5G 8/1
5G 8/1
5G 8/1
N3
N7
5G 8/1

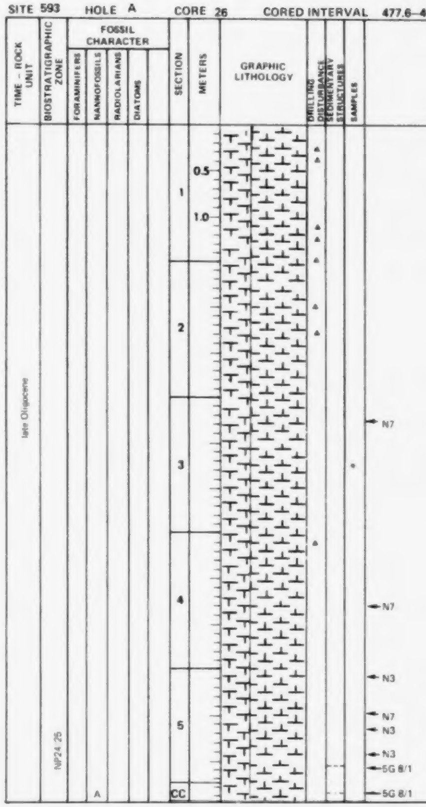
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, white (N9) to light greenish gray (5GY 8/1), firm to stiff, homogeneous. Light gray (N7) and dark gray (N3) and light greenish gray (5G 8/1) lamina are present.

SMEAR SLIDE SUMMARY

	3, 80 D	4, 50 M
Texture		
Silt	C	C
Clay	D	D
Composition		
Quartz	T	T
Feldspar	T	-
Volcanic glass	T	T
Carbonate unspec	T	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 593 HOLE A CORE 26 CORED INTERVAL 477.6–487.2 m


TIME - ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Oligocene
NP24.25
A
1
2
3
4
5
CC
0.5
1.0
N7
N7
N3
N7
N3
N3
5G 8/1
5G 8/1

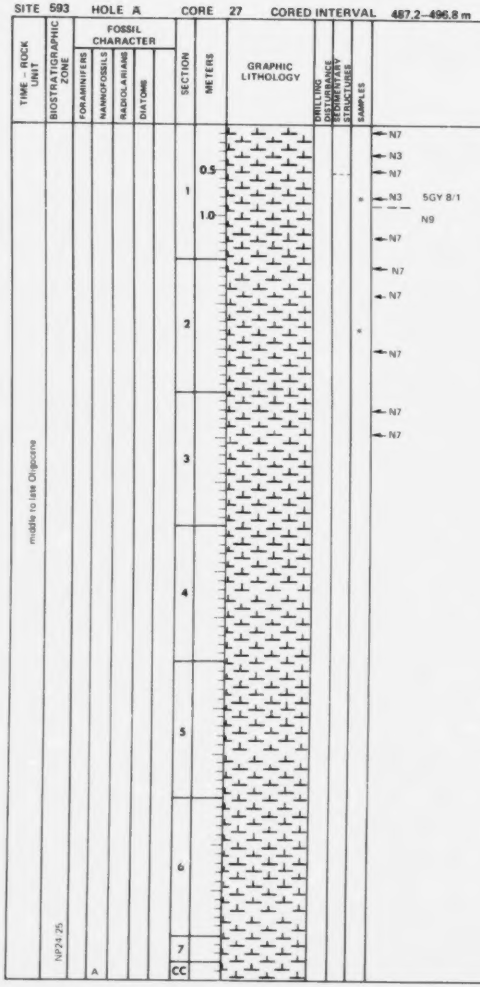
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light greenish gray (5GY 8/1), homogeneous, firm to stiff, partly lithified. Rare light gray (N7), dark gray (N3) or light greenish gray (5G 8/1) laminae.

SMEAR SLIDE SUMMARY

	3, 80 D
Texture:	
Sand	R
Silt	C
Clay	A
Composition:	
Quartz	T
Mica	T
Volcanic glass	T
Carbonate unspec.	T
Foraminifers	C/A
Calc. nannofossils	A/D

SITE 593 HOLE A CORE 27 CORED INTERVAL 487.2–496.8 m

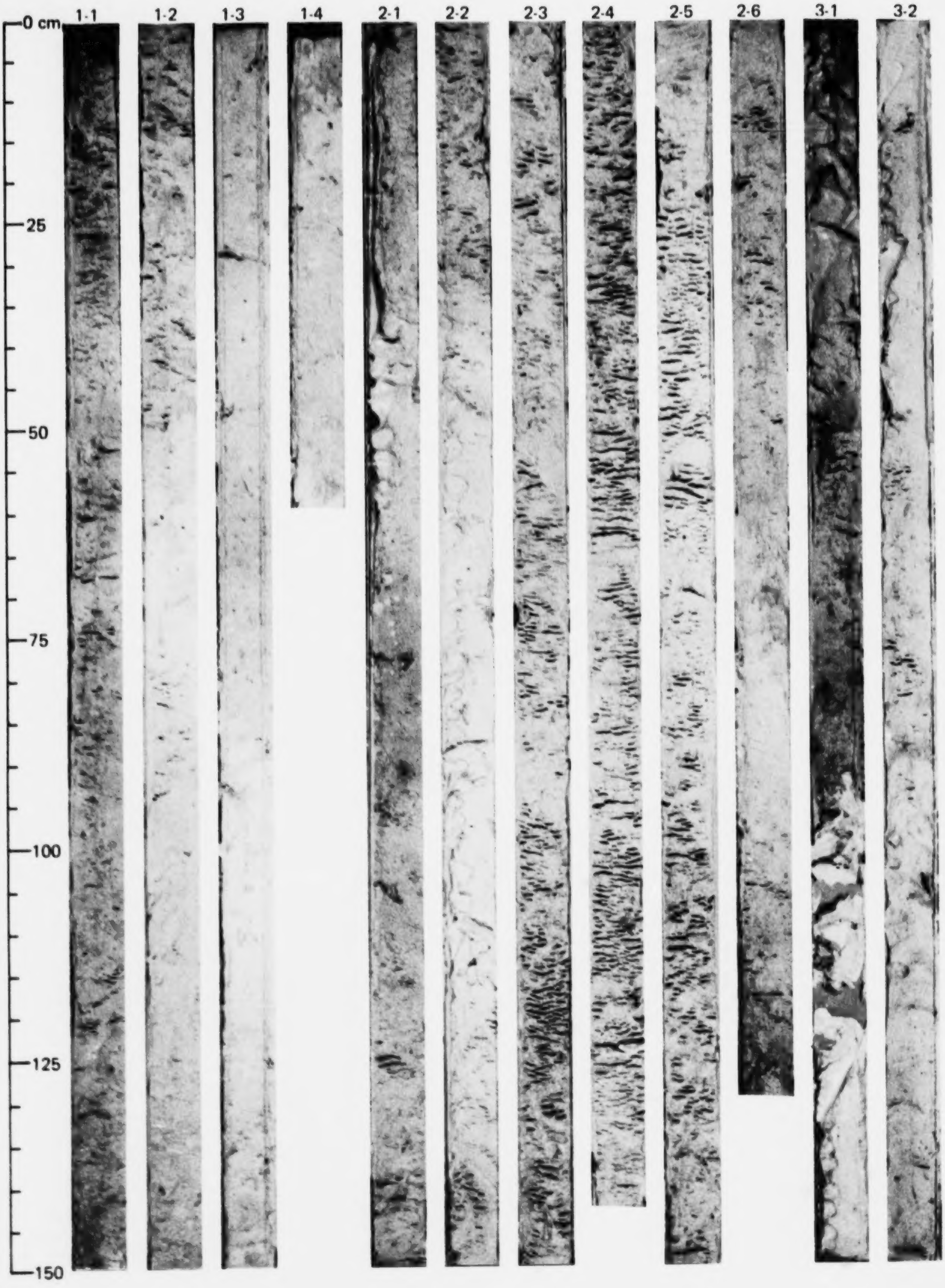

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle to late Oligocene
NP24-25
A
1
2
3
4
5
6
7
CC
0.5
1.0
N7
N3
N7
N3
5GY 8/1
N9
N7
N7
N7
N7
N7
N7

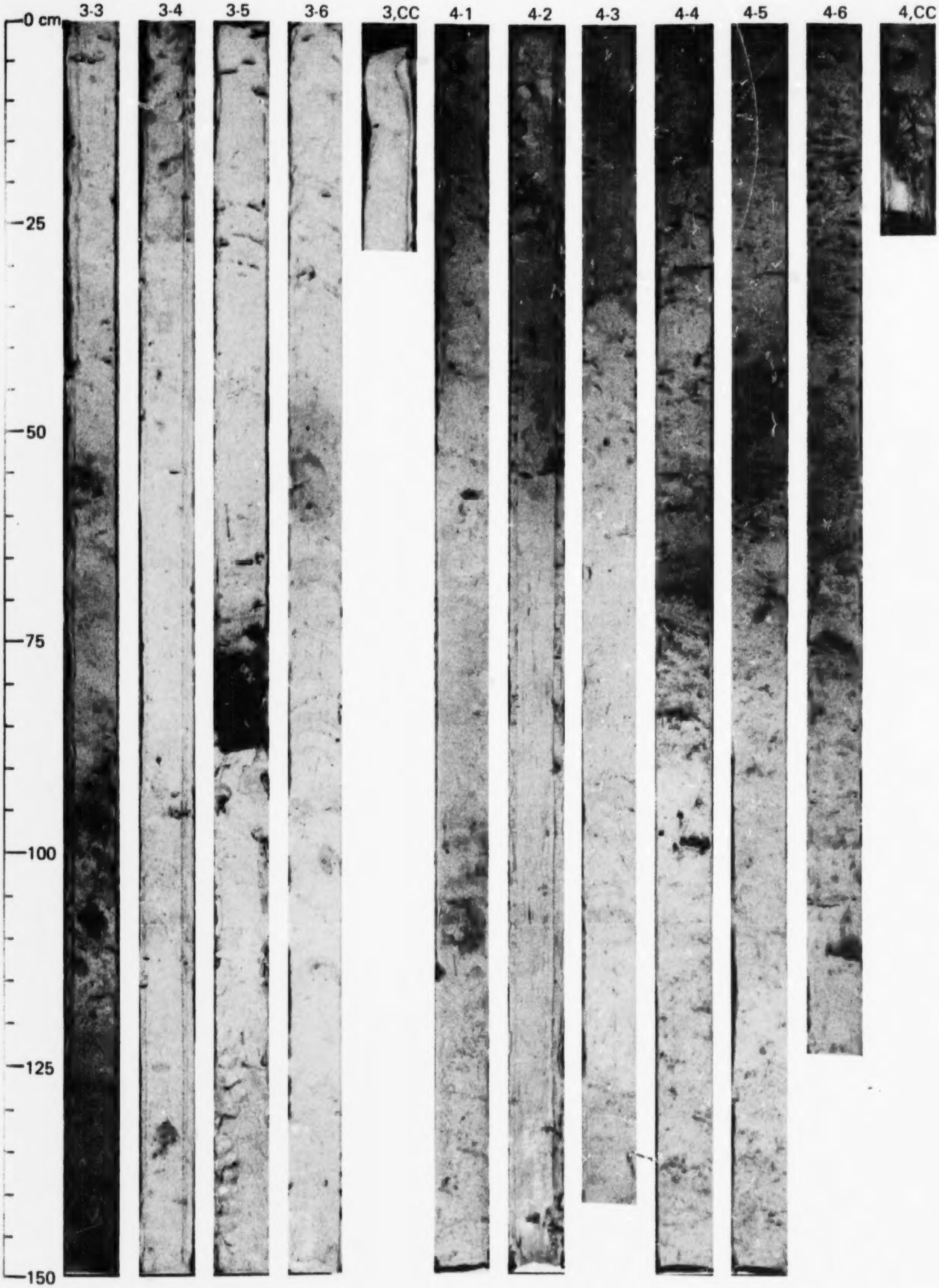
LITHOLOGIC DESCRIPTION

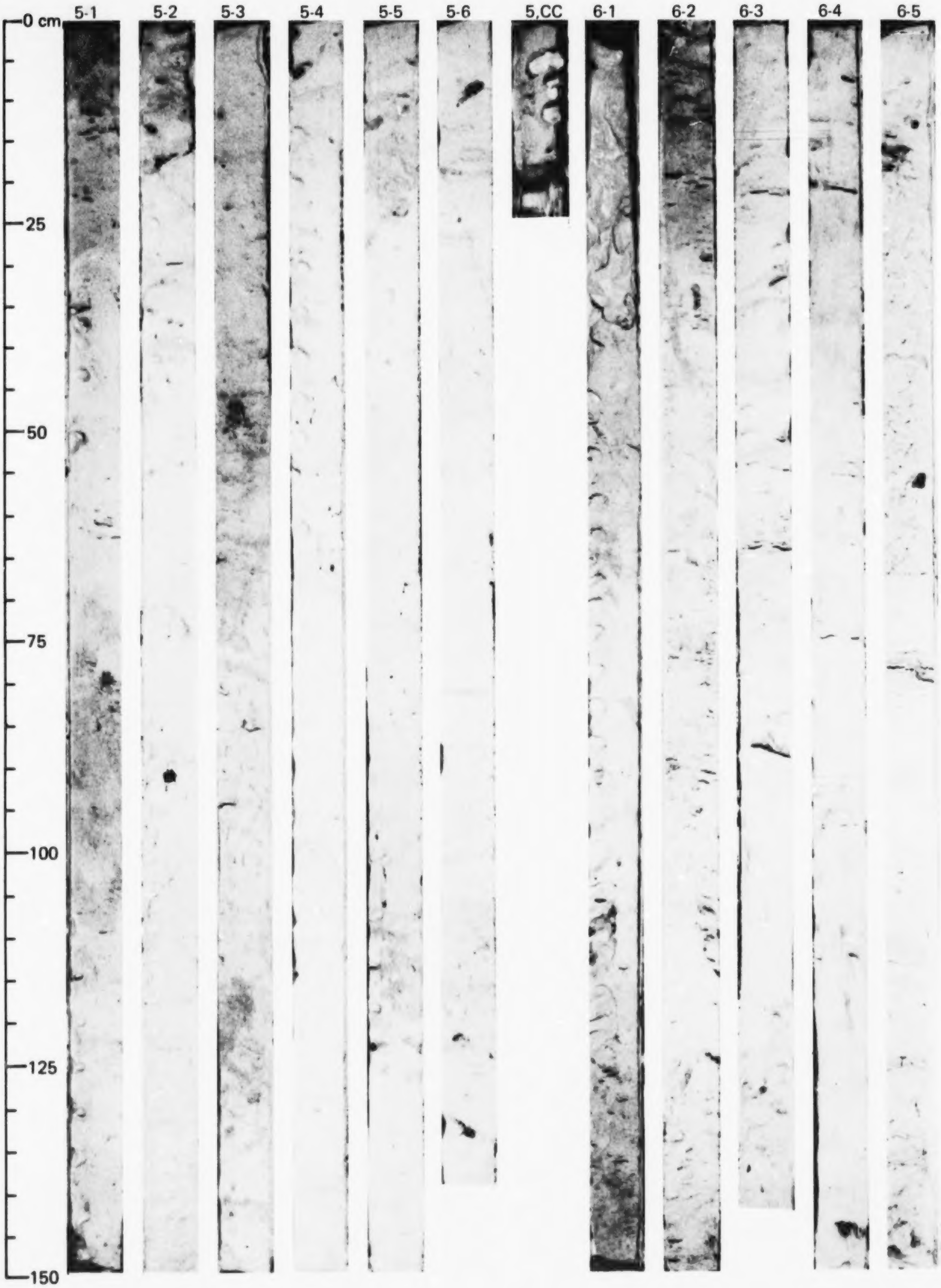
NANNOFOSSIL OOZE, light greenish gray (5GY 8/1) in Section 1 (0.95), then white (N9), homogeneous, firm to stiff. Light gray (N7) and dark gray (N3) laminae occur.

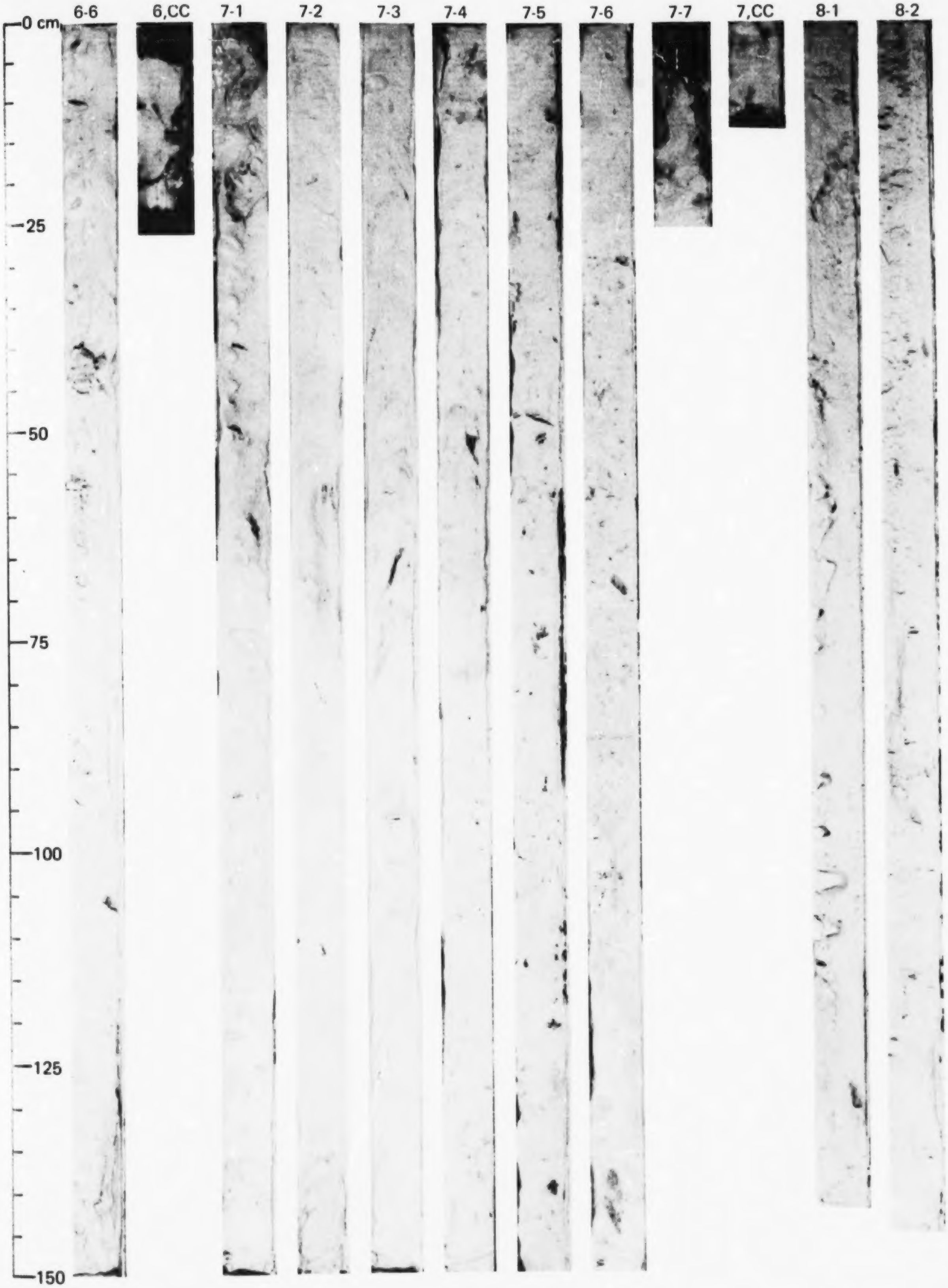
SMEAR SLIDE SUMMARY

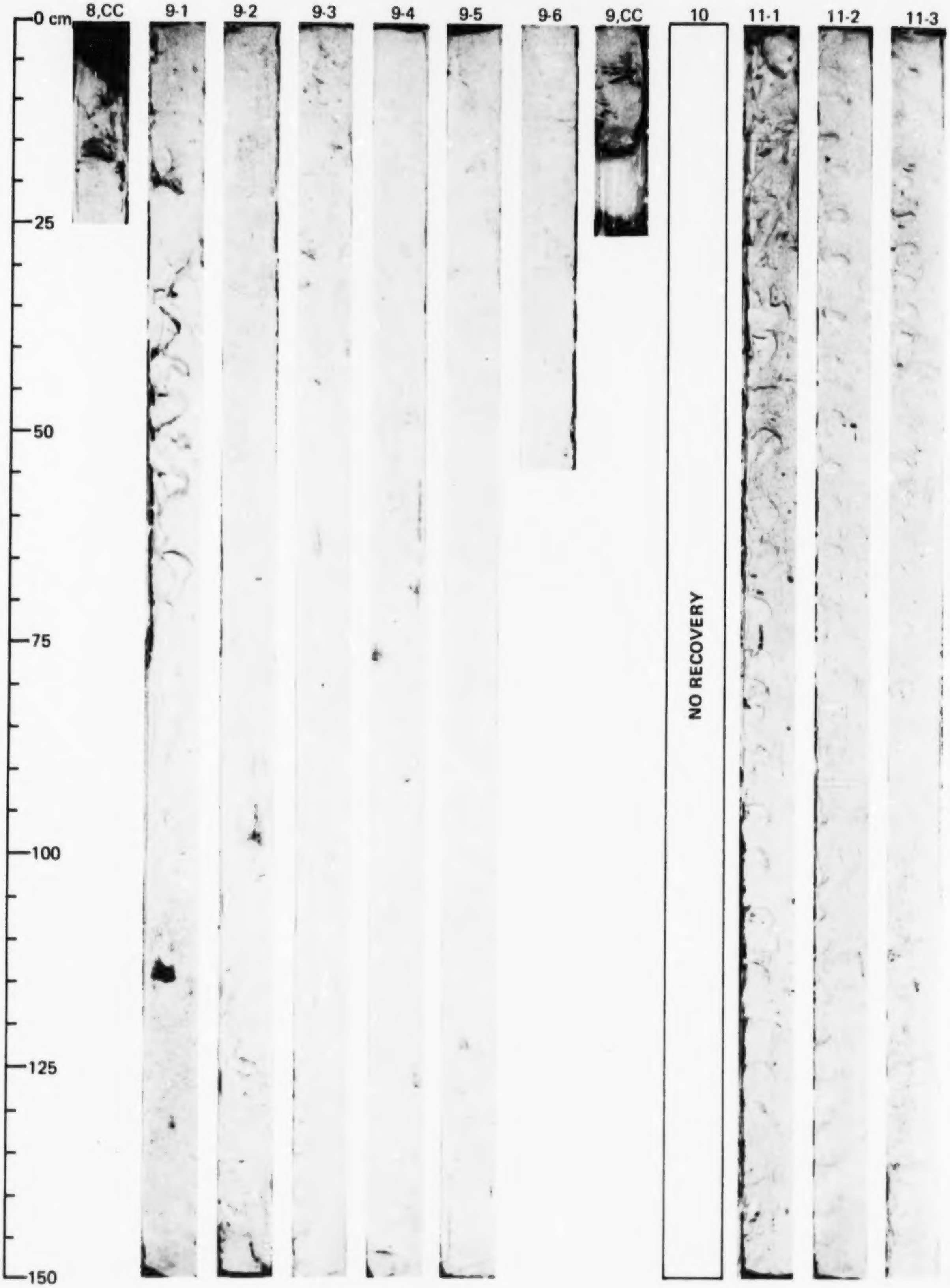
	1, 90	3, 80
	D	D
Texture:		
Silt	R	–
Clay	D	D
Composition:		
Quartz	T	–
Feldspar	T	T
Mica	T	–
Volcanic glass	T	T
Carbonate unspec	T	R
Foraminifers	R/C	T/R
Calc. nannofossils	D	D
Dolomite	–	T

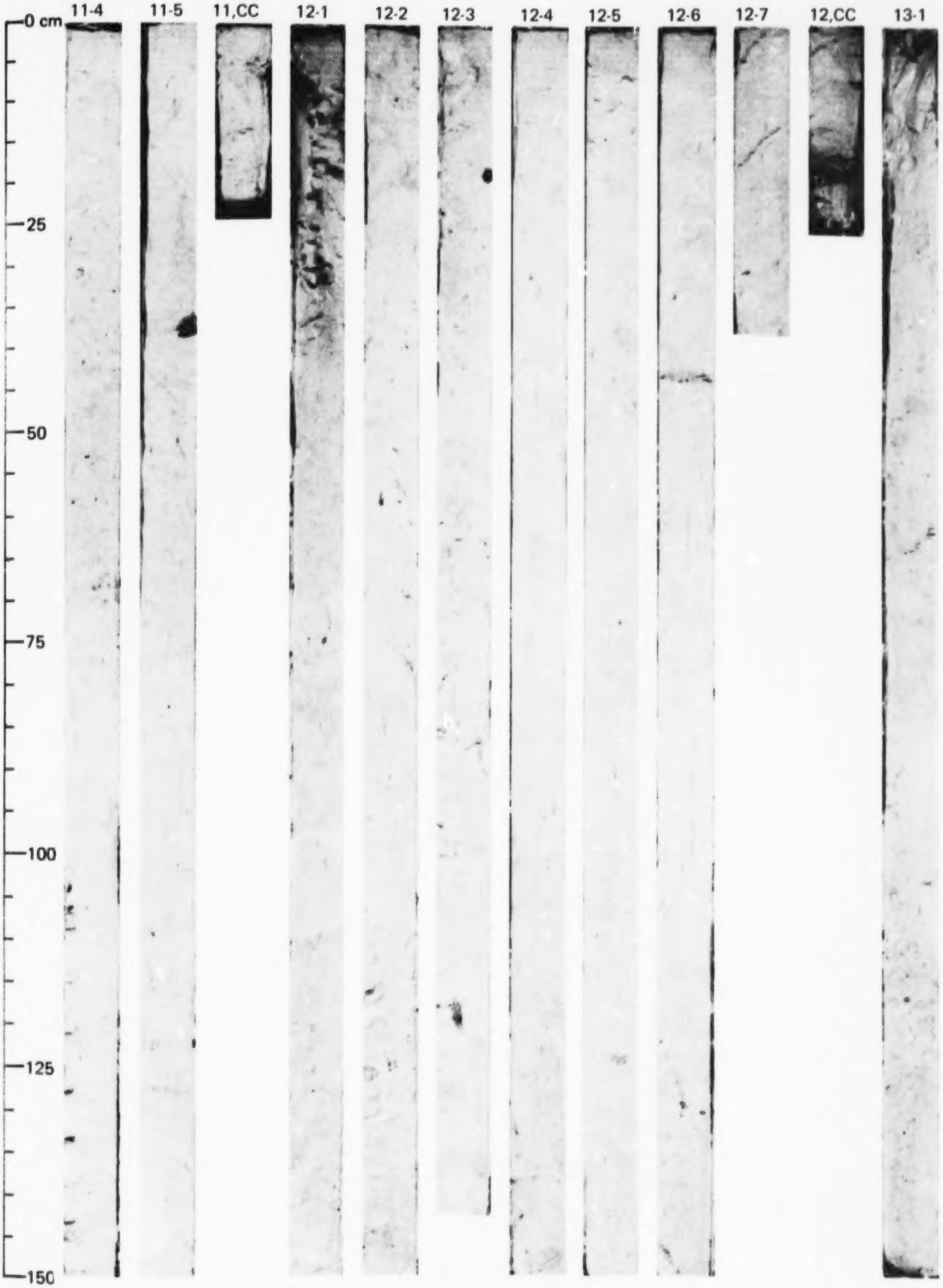

1-1
1-2
1-3
1-4
2-1
2-2
2-3
2-4
2-5
2-6
3-1
3-2
0 cm
25
50
75
100
125
150

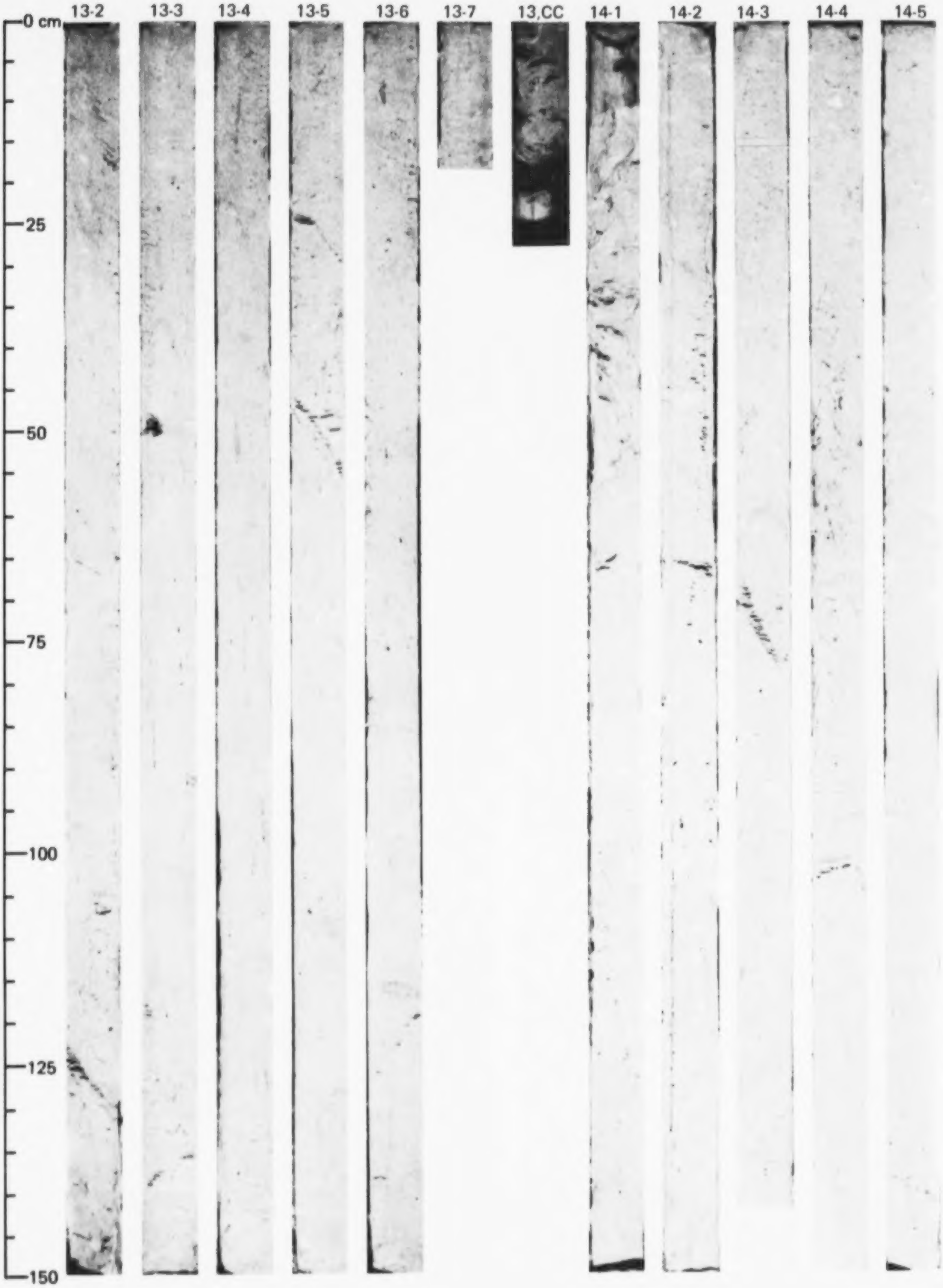

3-3
3-4
3-5
3-6
3,CC
4-1
4-2
4-3
4-4
4-5
4-6
4,CC
0 cm
25
50
75
100
125
150

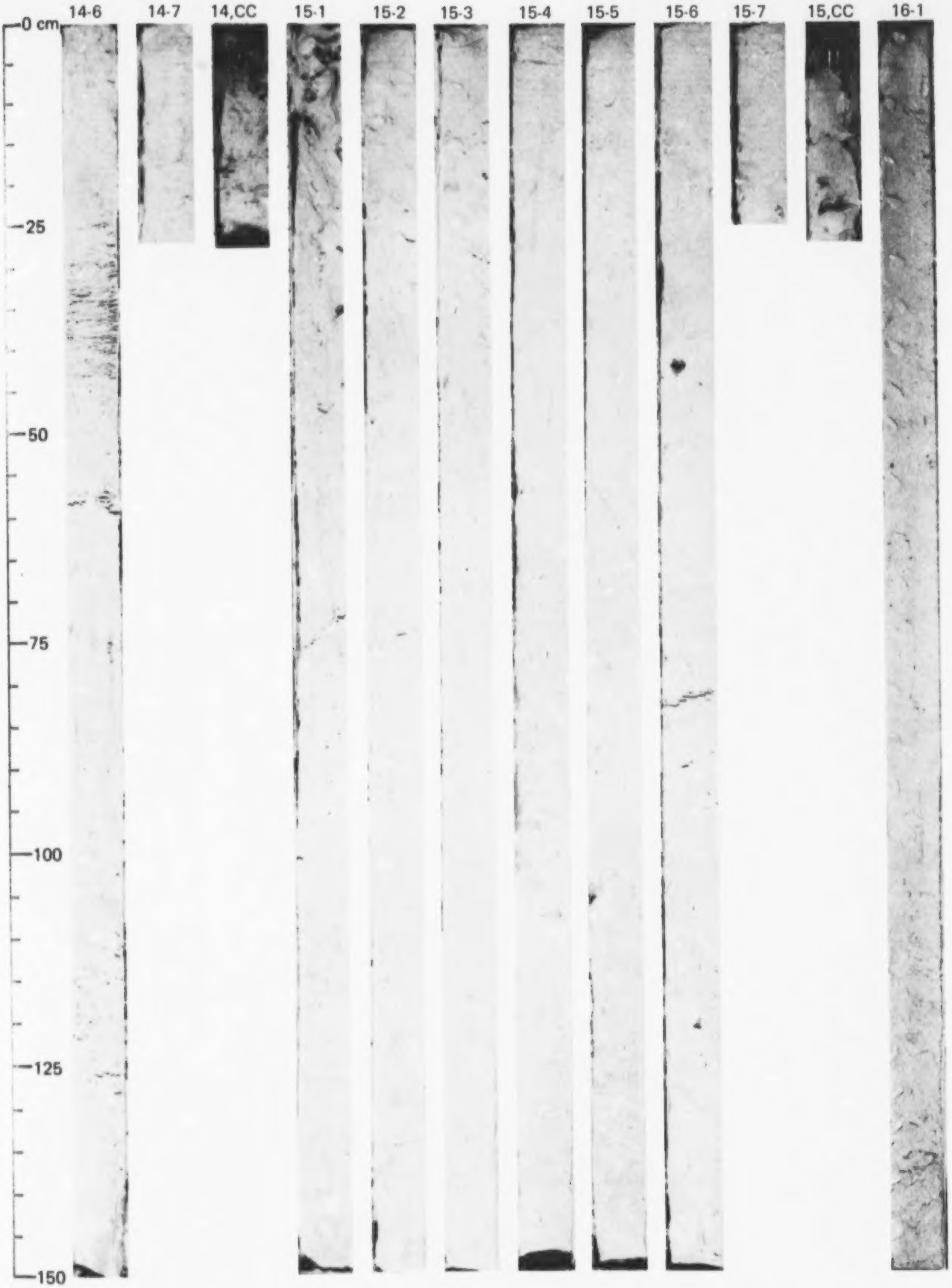

5-1
5-2
5-3
5-4
5-5
5-6
5,CC
6-1
6-2
6-3
6-4
6-5
0 cm
25
50
75
100
125
150


6-6
6,CC
7-1
7-2
7-3
7-4
7-5
7-6
7-7
7,CC
8-1
8-2
0 cm
25
50
75
100
125
150

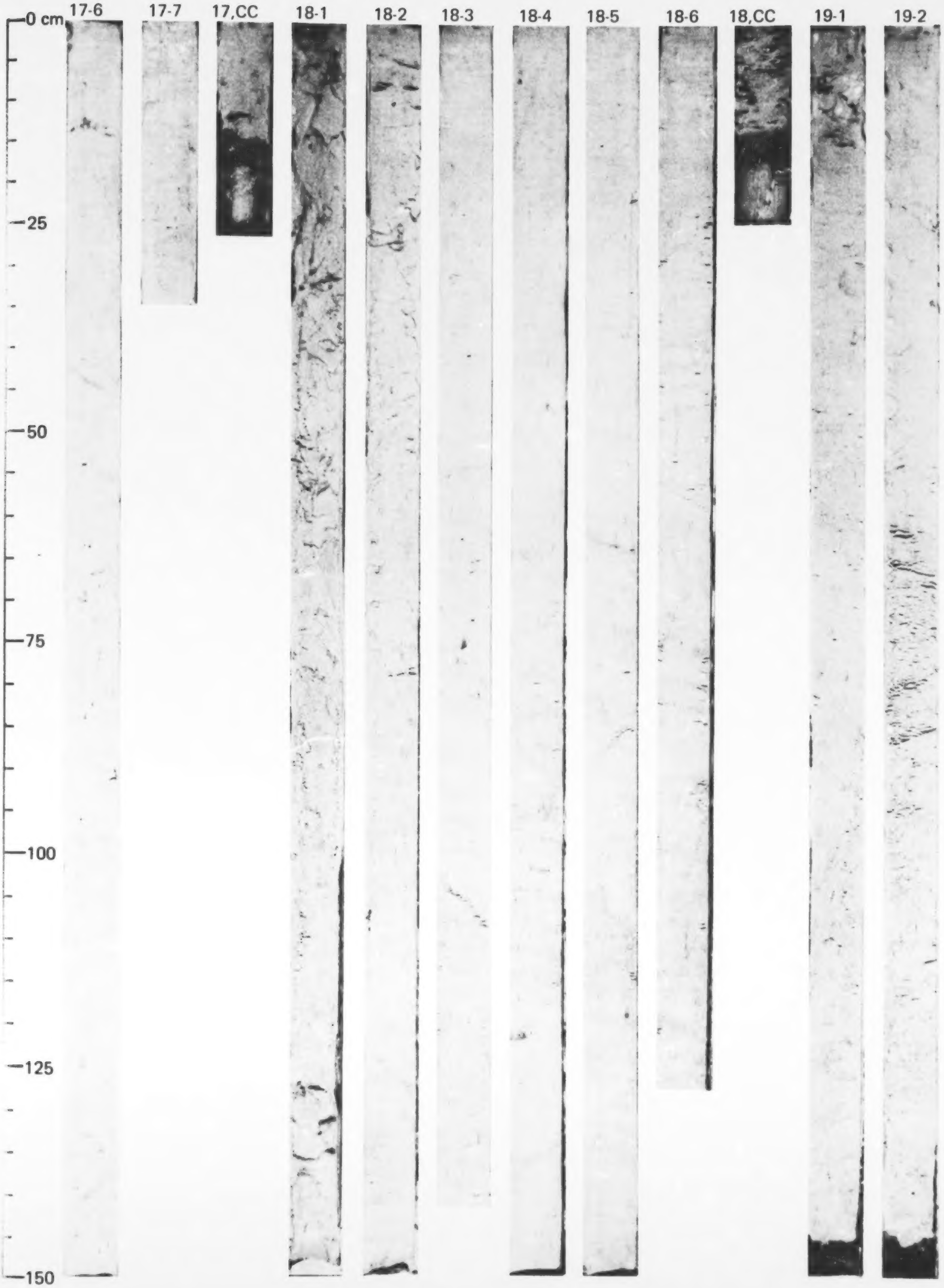

0 cm
25
50
75
100
125
150
8,CC
9-1
9-2
9-3
9-4
9-5
9-6
9,CC
10
11-1
11-2
11-3
NO RECOVERY

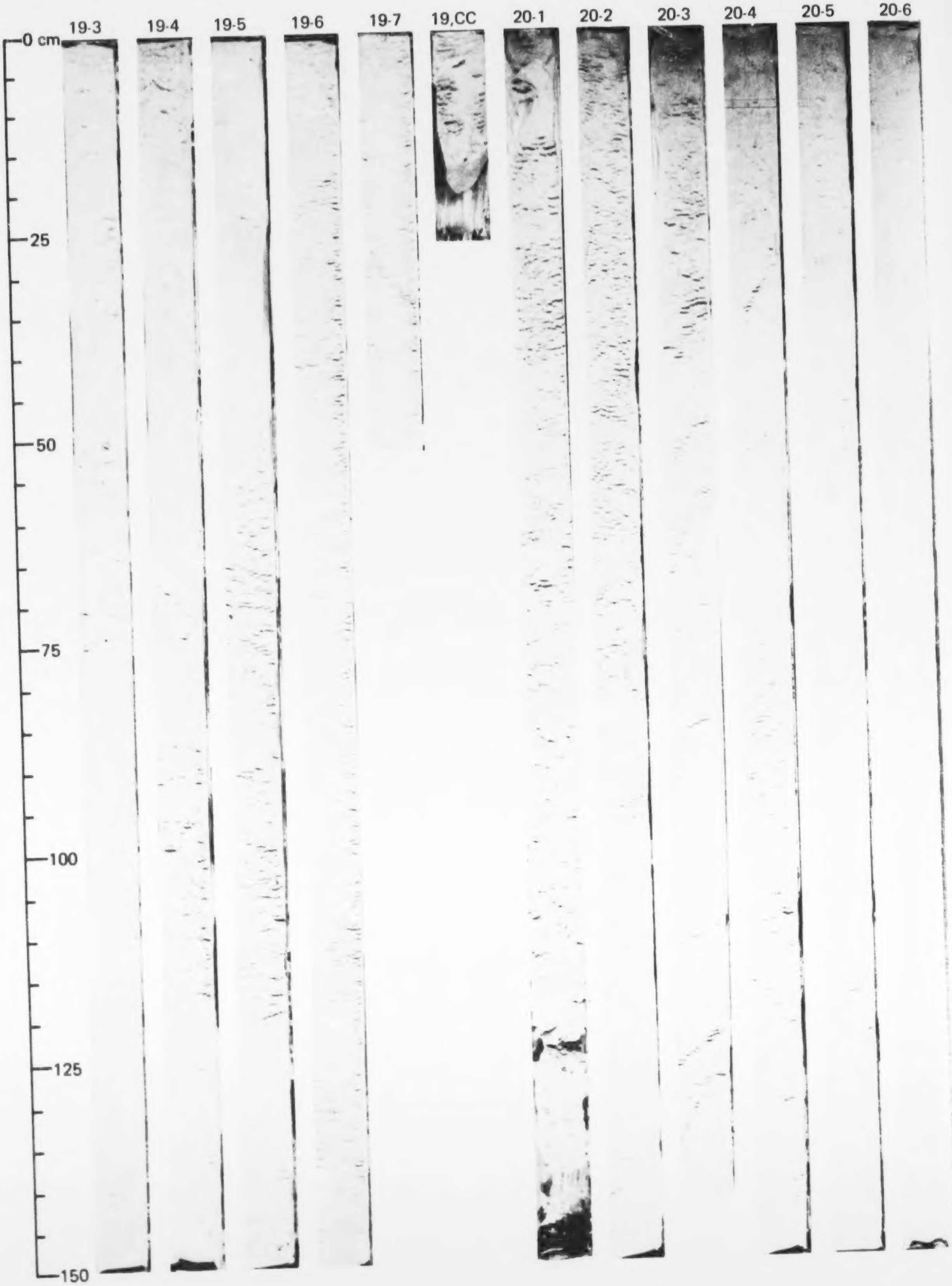

11-4
11-5
11,CC
12-1
12-2
12-3
12-4
12-5
12-6
12-7
12,CC
13-1
0 cm
25
50
75
100
125
150

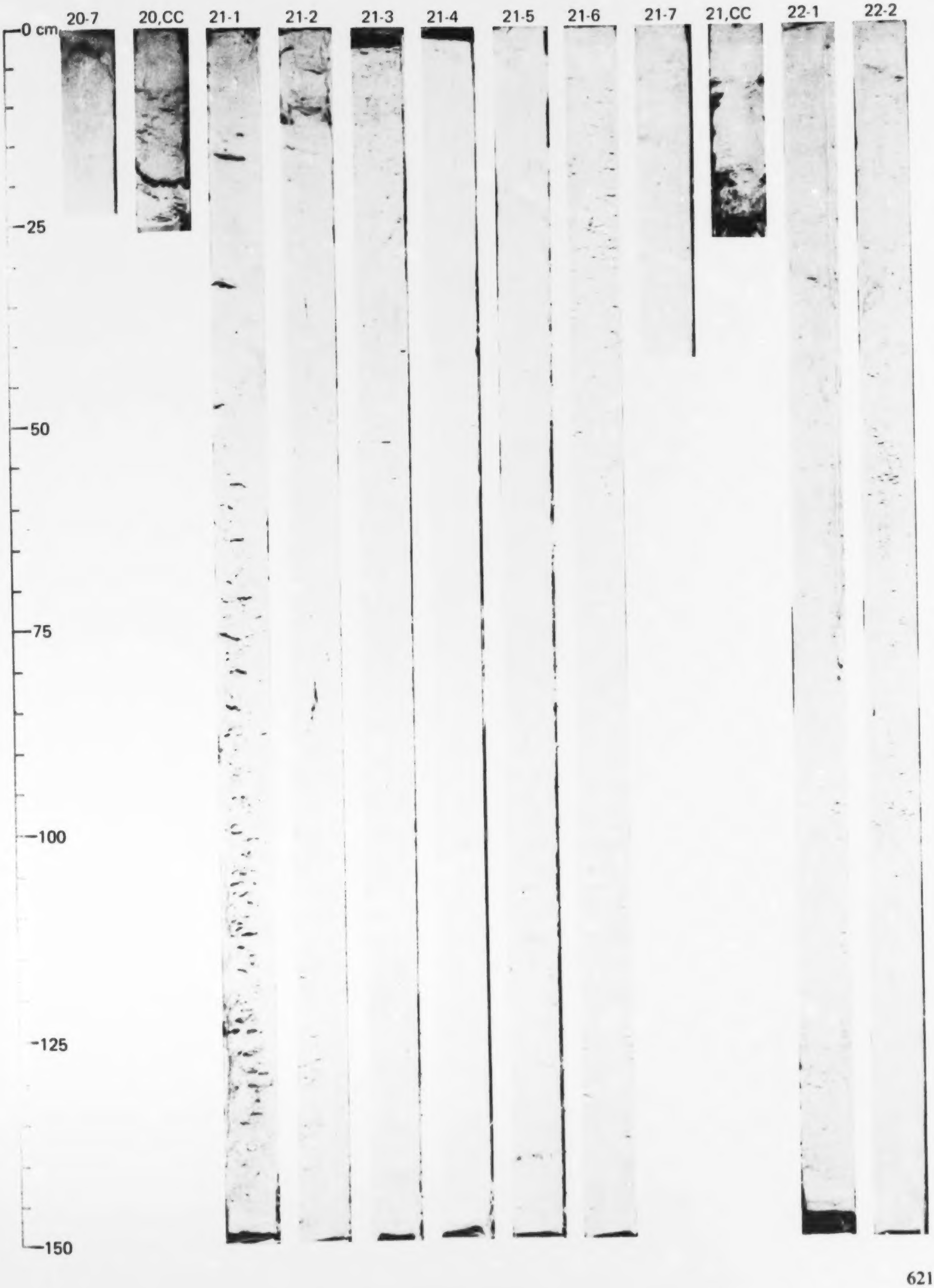

13-2
13-3
13-4
13-5
13-6
13-7
13,CC
14-1
14-2
14-3
14-4
14-5
0 cm
25
50
75
100
125
150


14-6
14-7
14,CC
15-1
15-2
15-3
15-4
15-5
15-6
15-7
15,CC
16-1
0 cm
25
50
75
100
125
150

0 cm
25
50
75
100
125
150
16-2
16-3
16-4
16-5
16-6
16-7
16,CC
17-1
17-2
17-3
17-4
17-5


0 cm
25
50
75
100
125
150
17-6
17-7
17,CC
18-1
18-2
18-3
18-4
18-5
18-6
18,CC
19-1
19-2


19-3
19-4
19-5
19-6
19-7
19,CC
20-1
20-2
20-3
20-4
20-5
20-6
0 cm
25
50
75
100
125
150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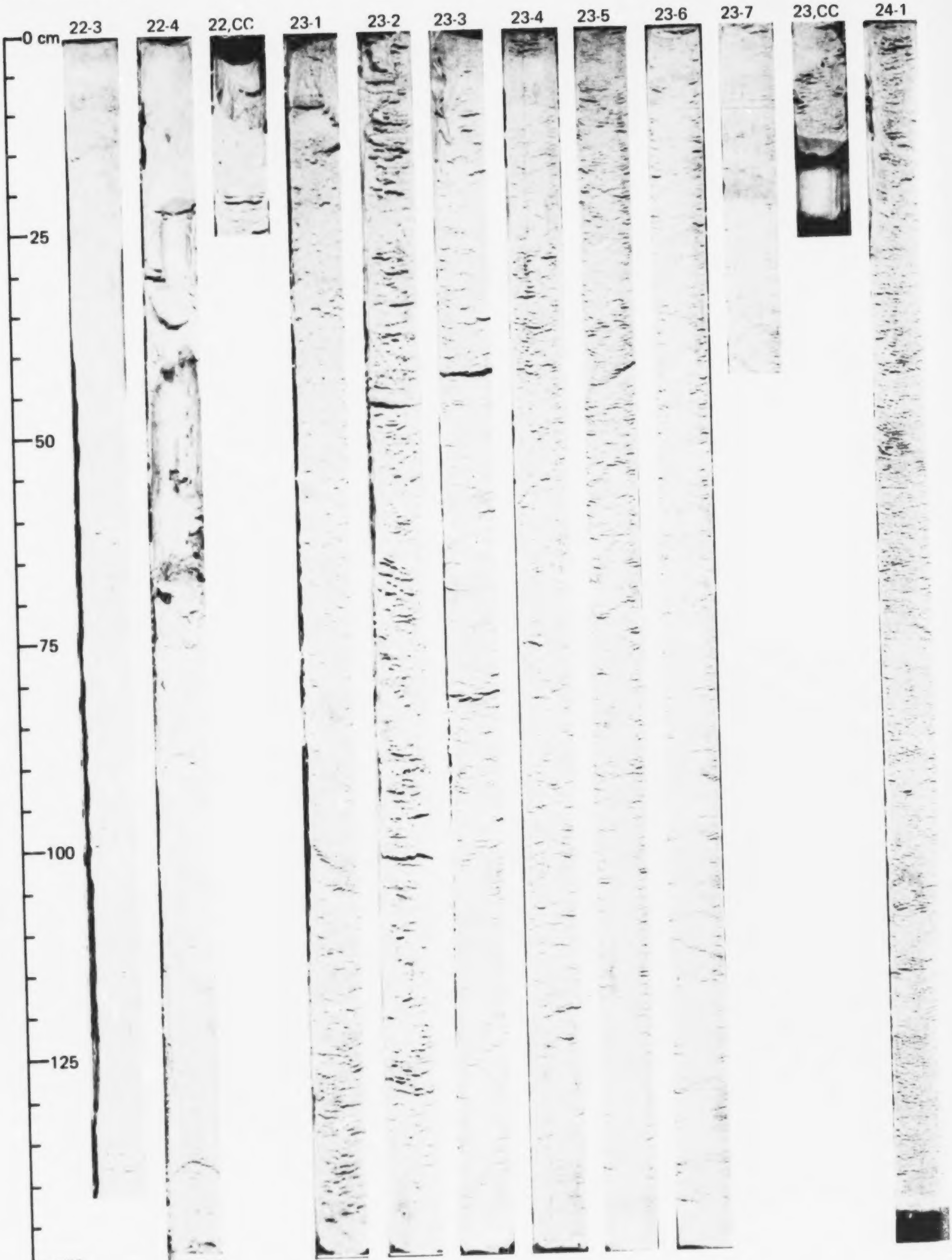
SITE 593 (HOLE 593)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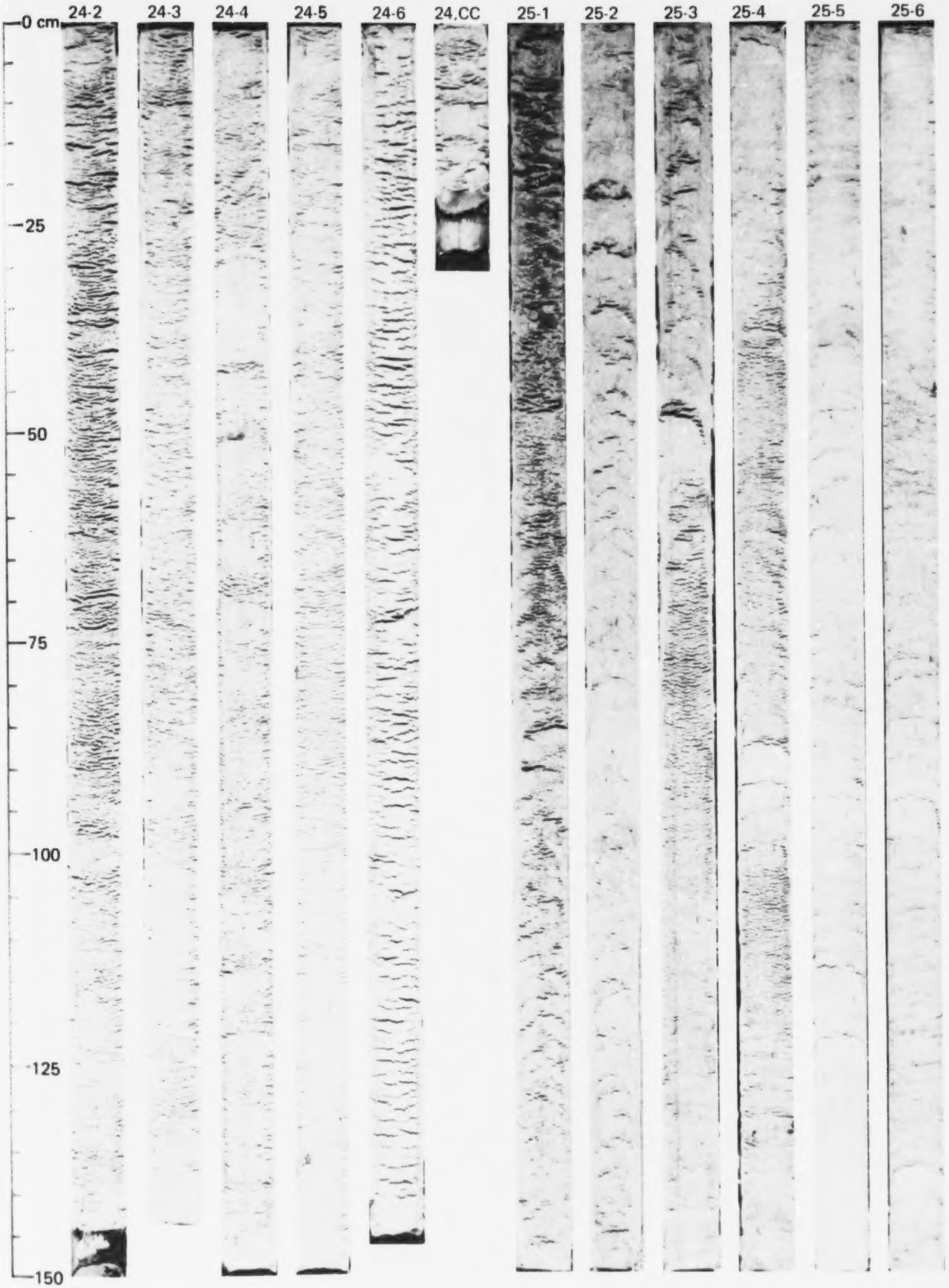
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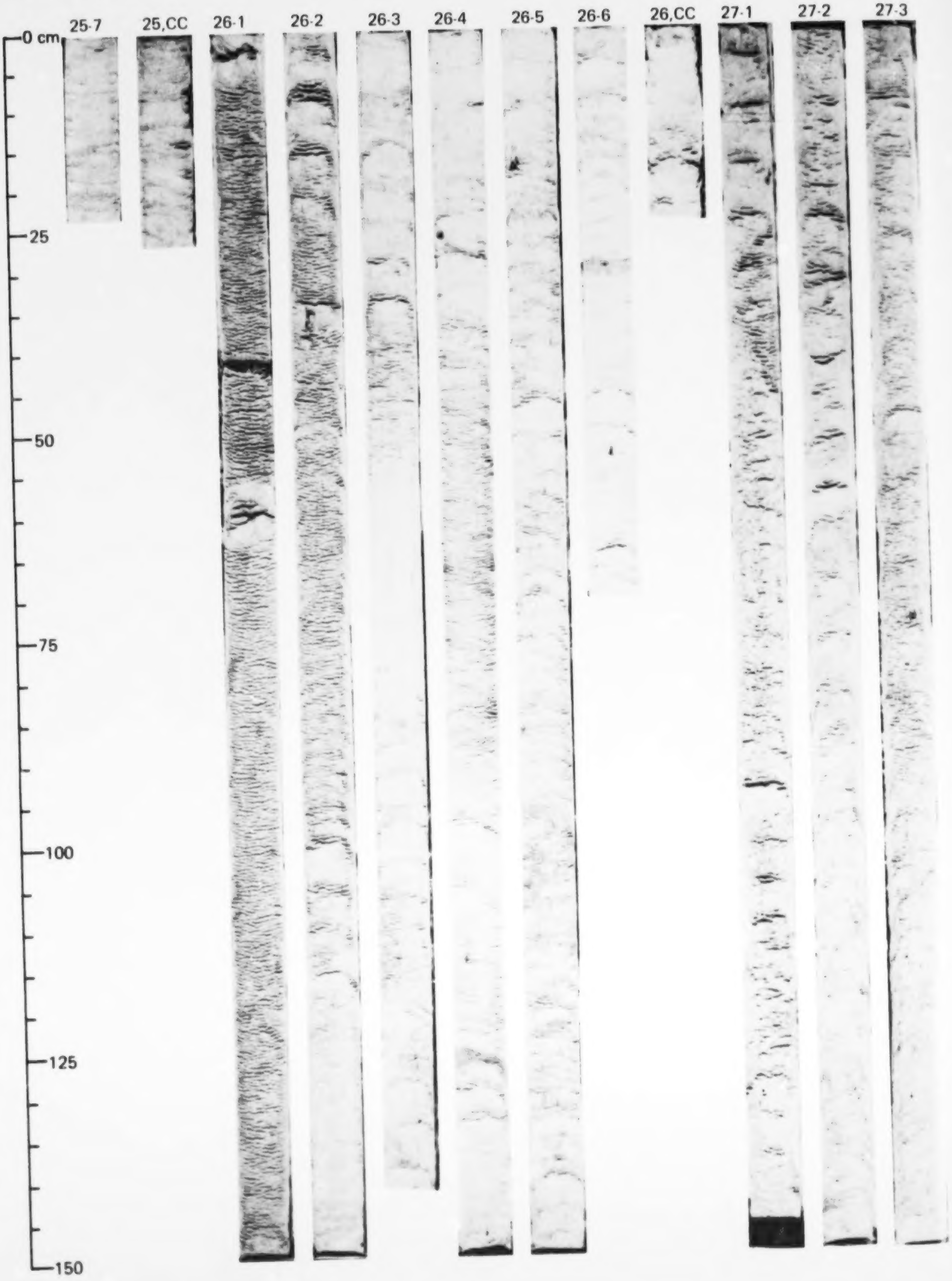
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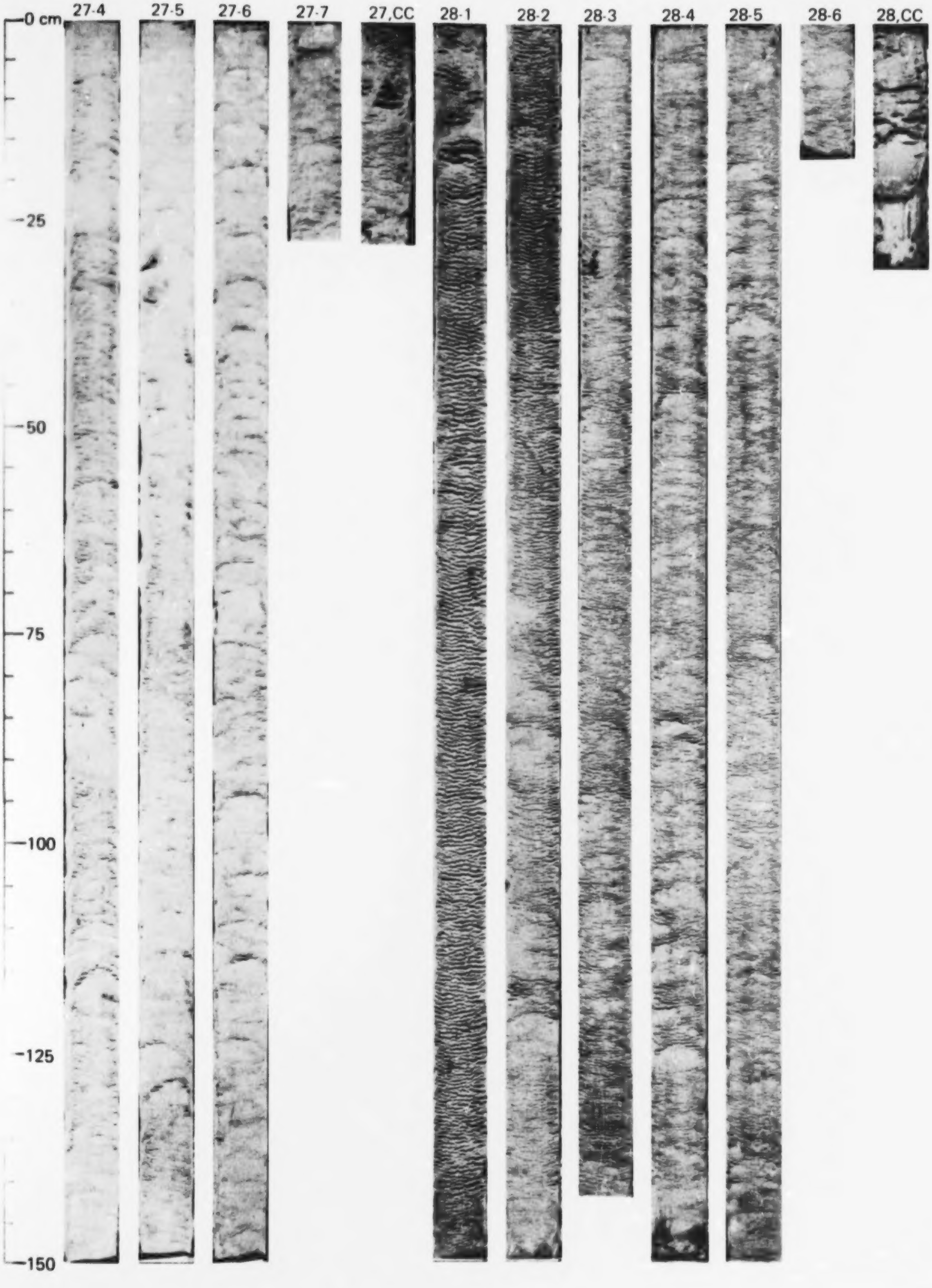
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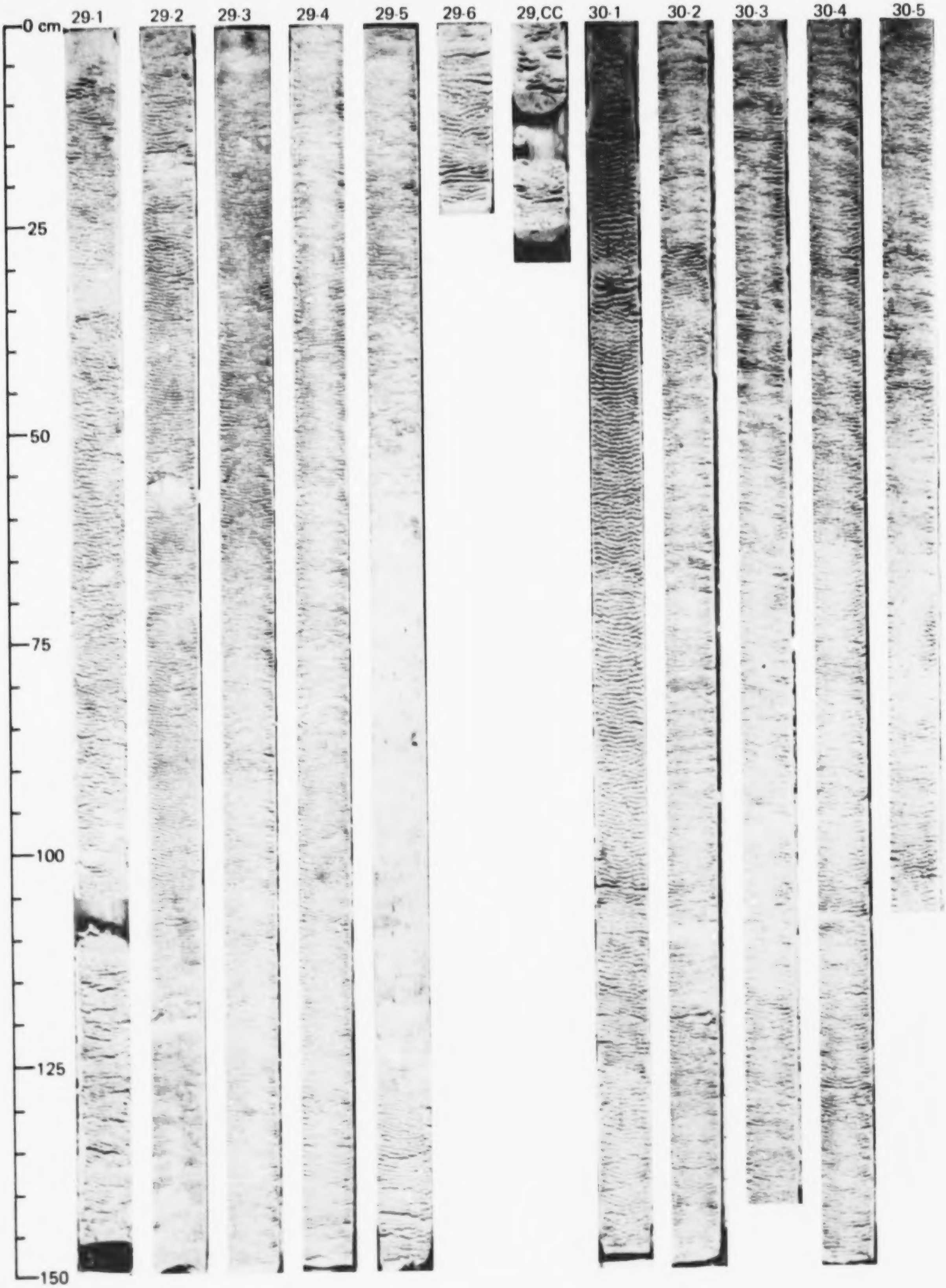
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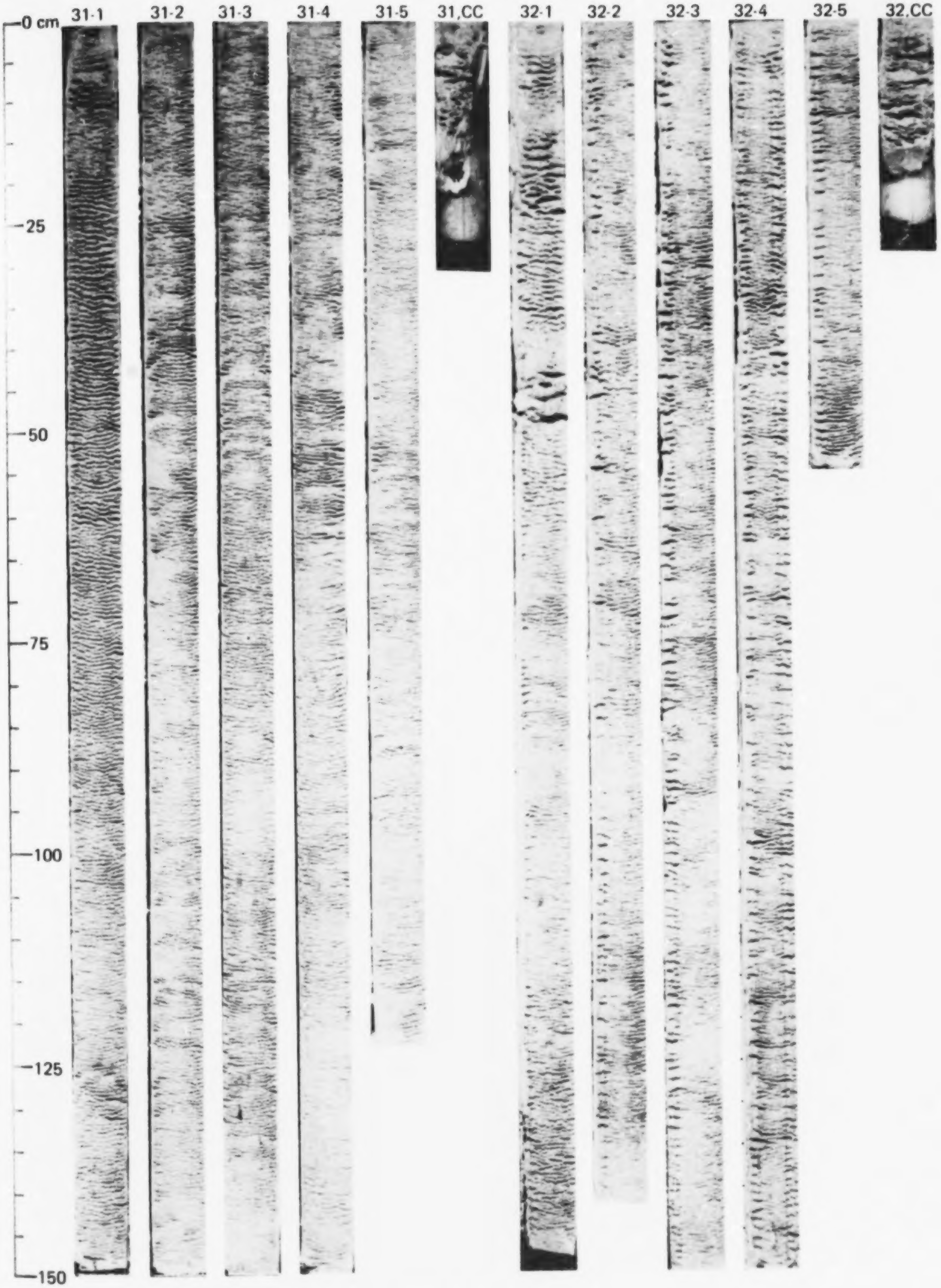
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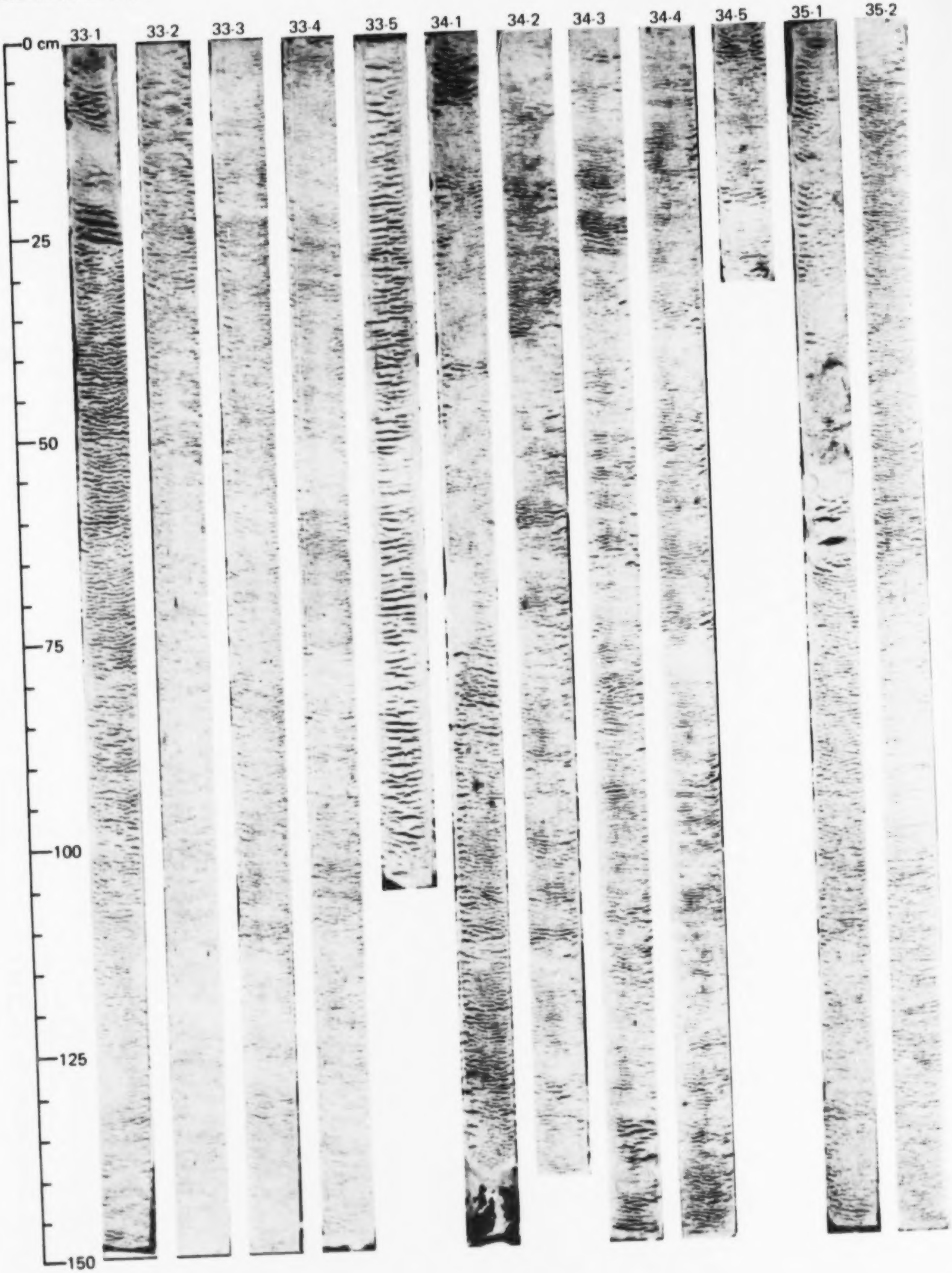
32-5
32,CC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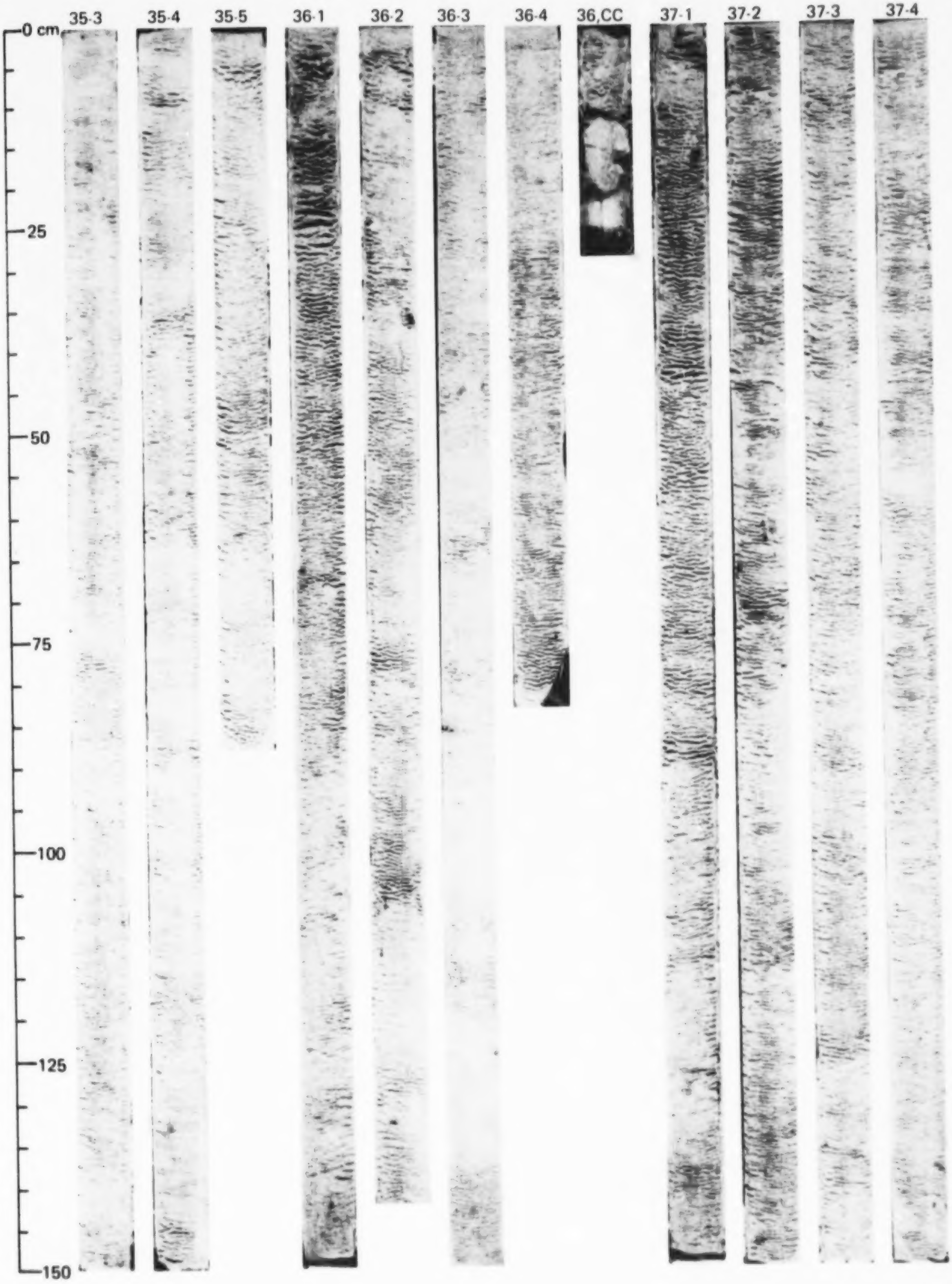
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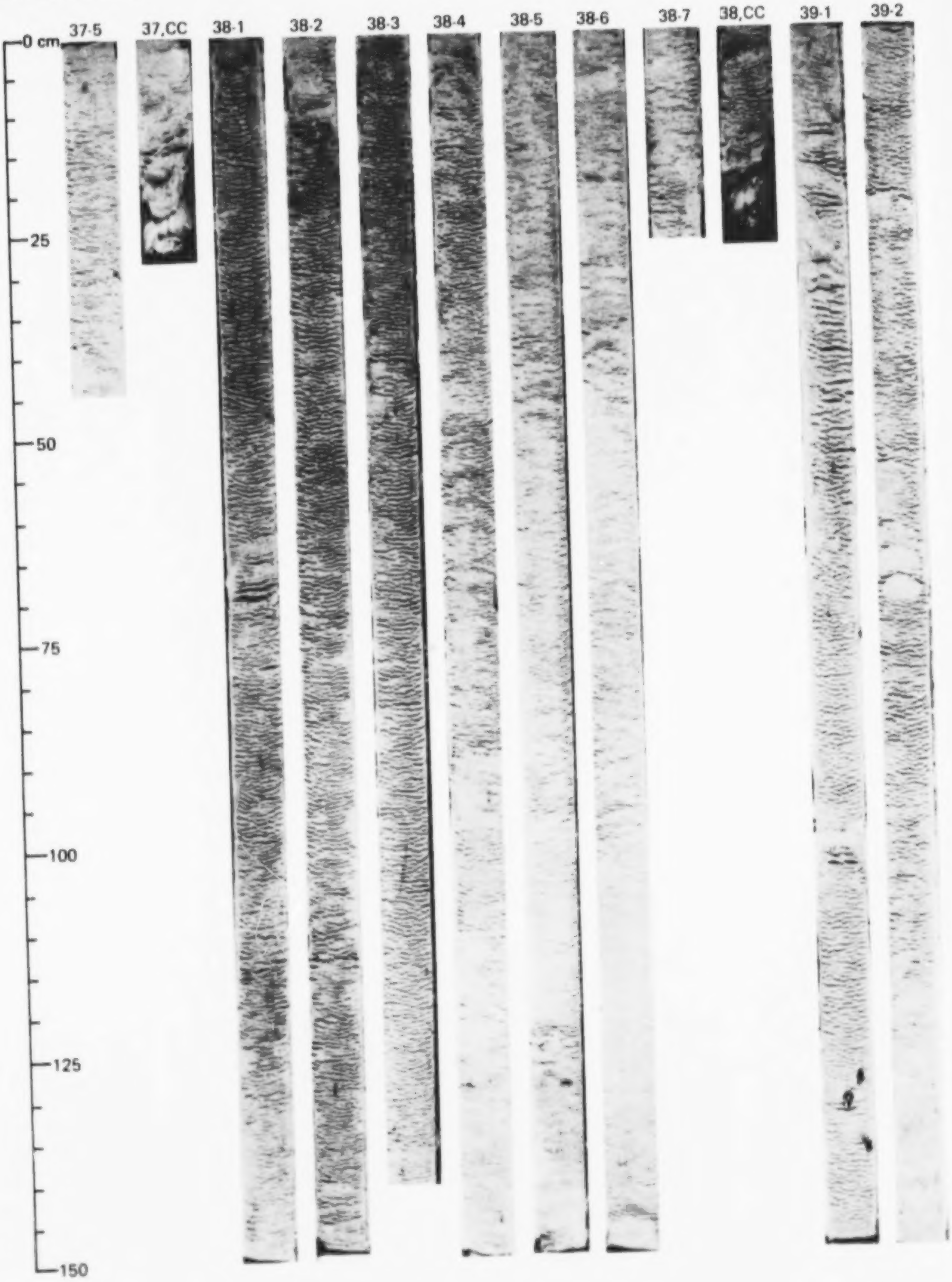
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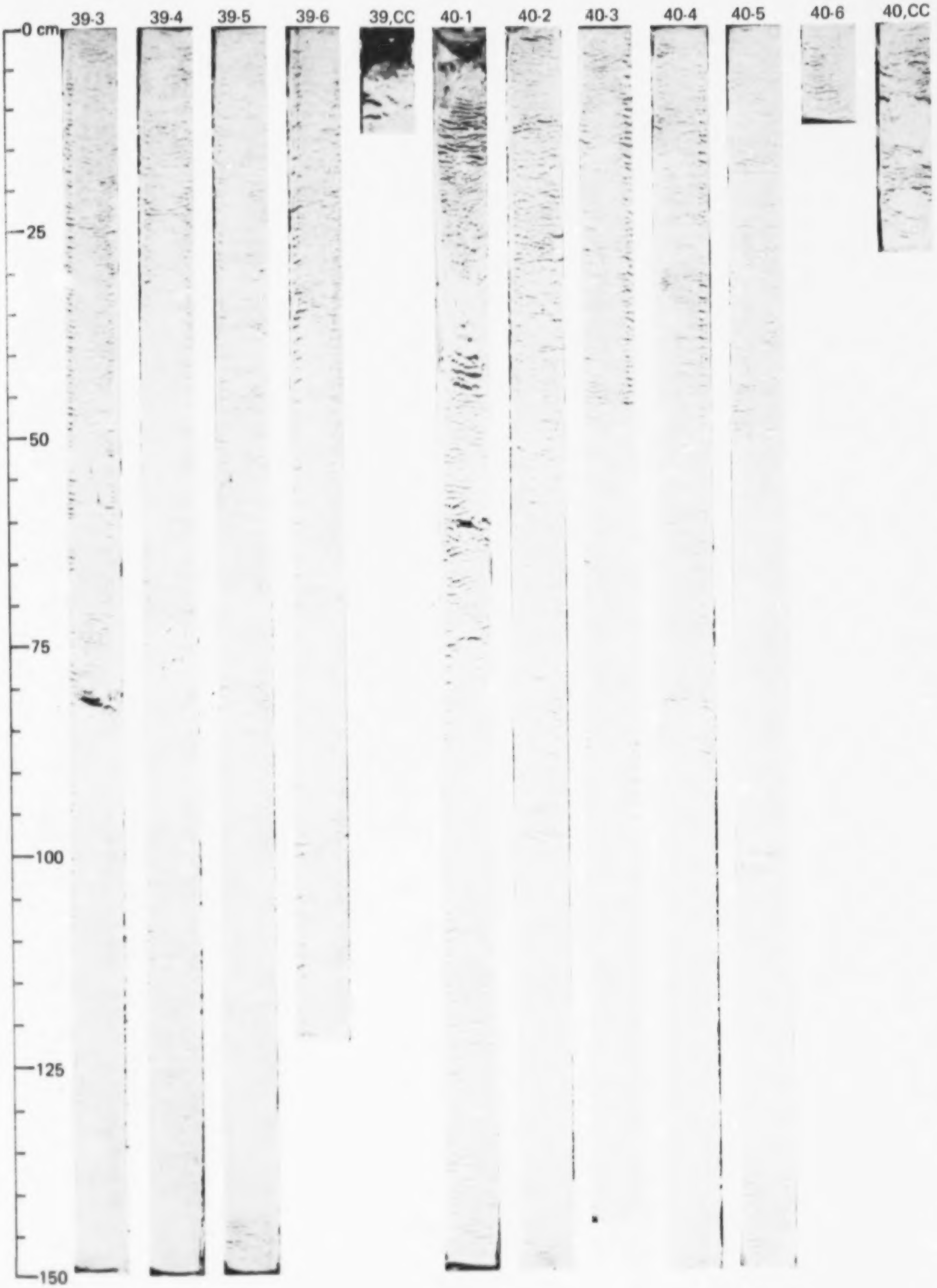
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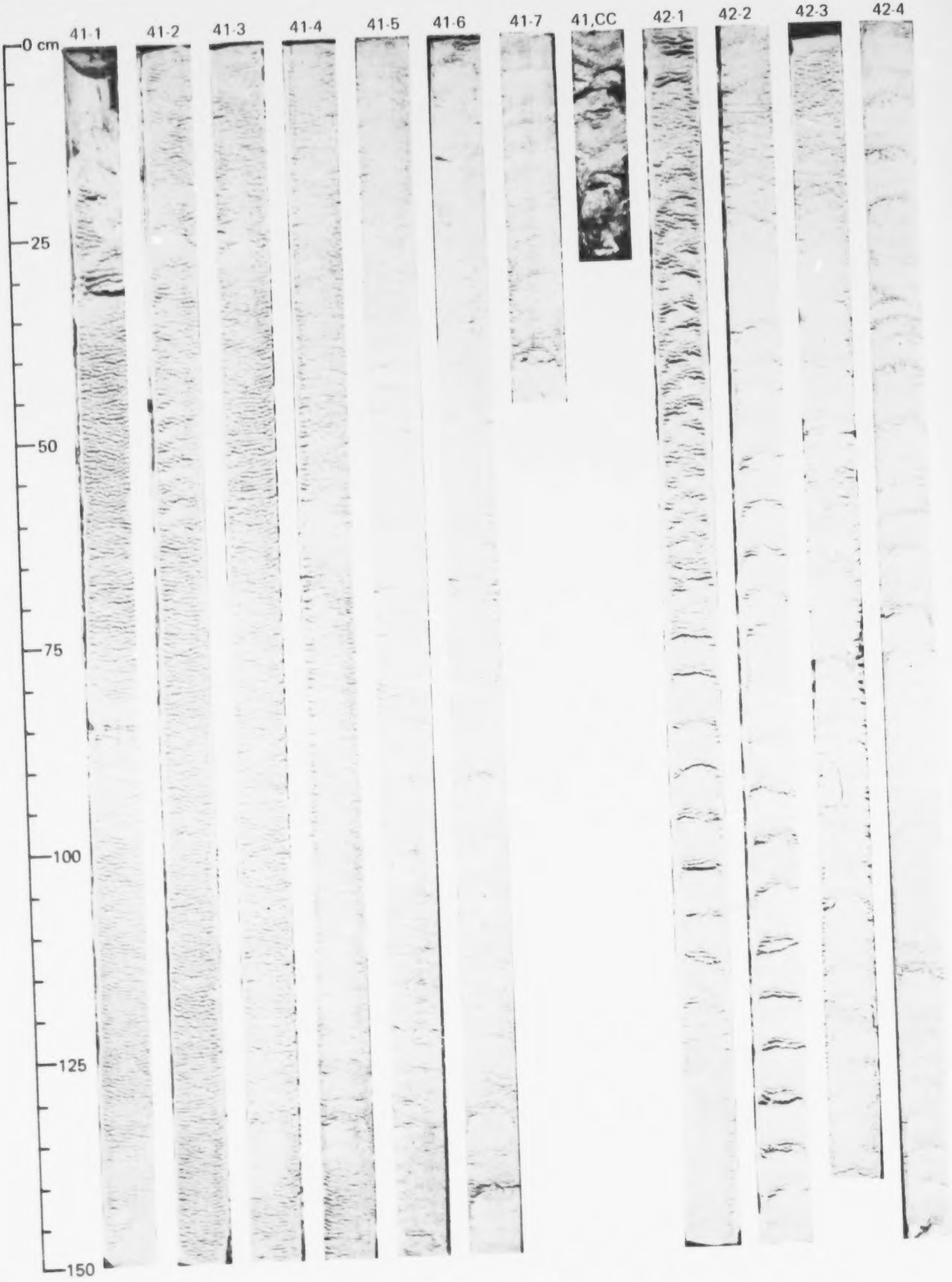
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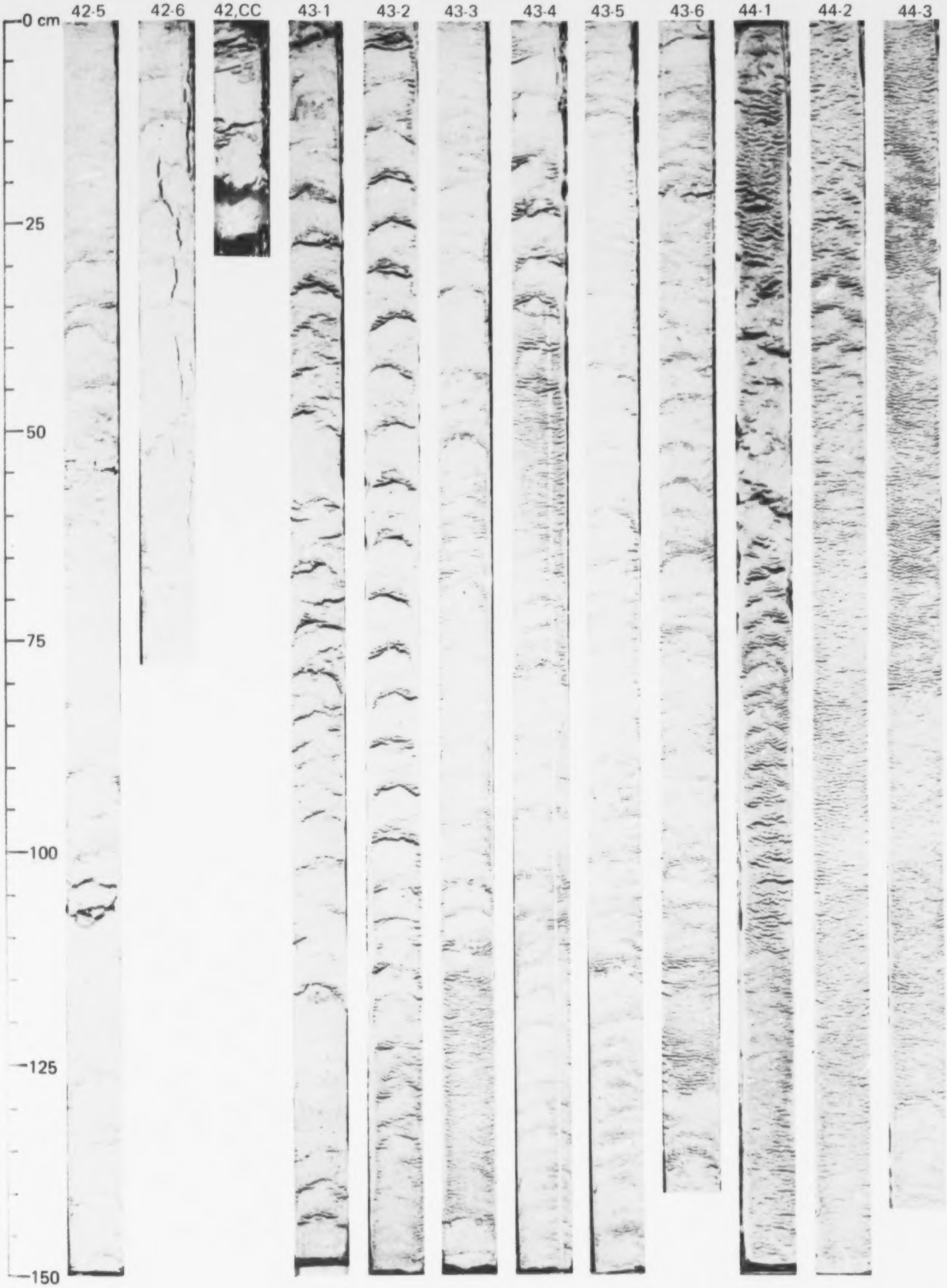
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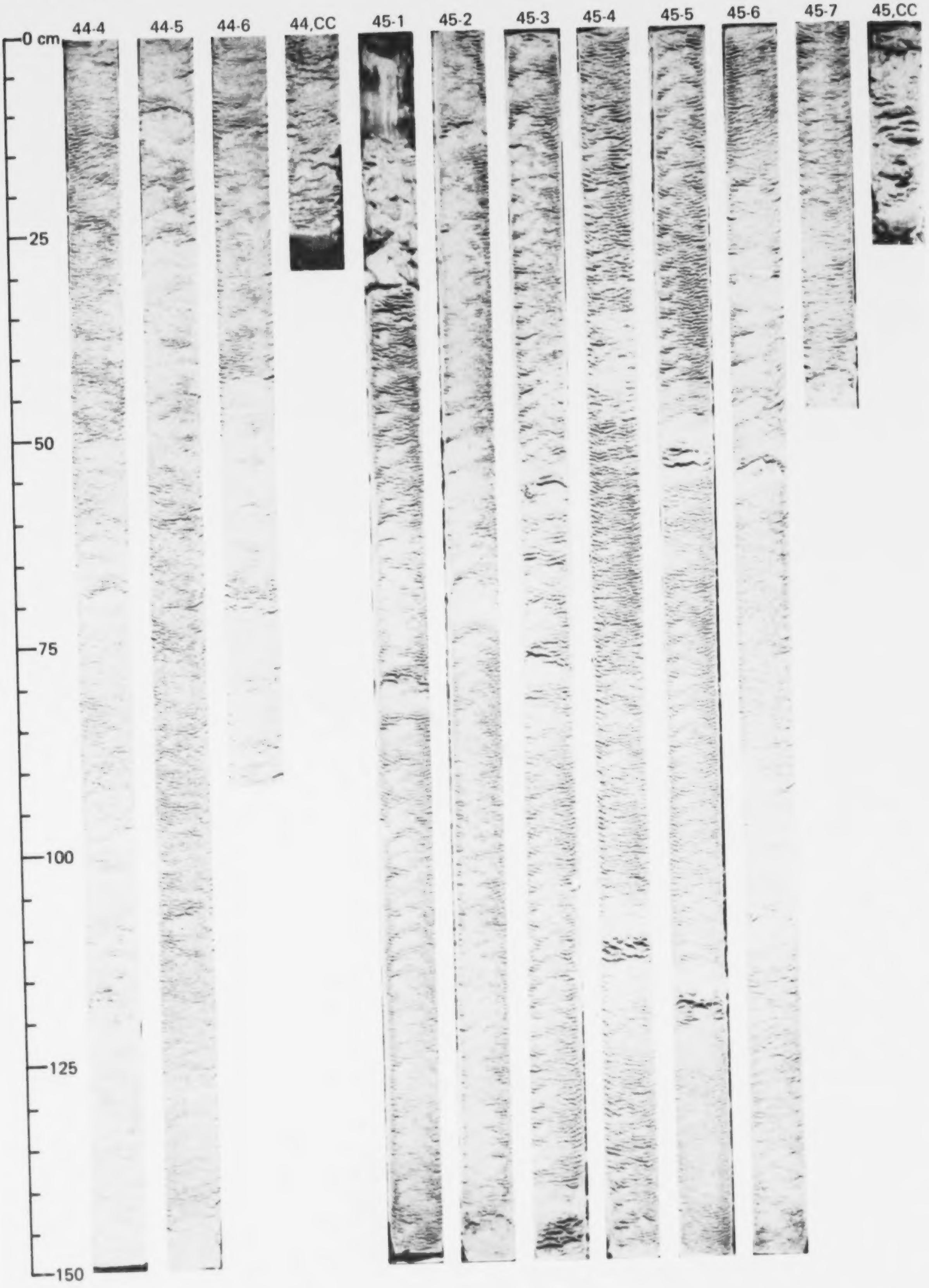
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45-7
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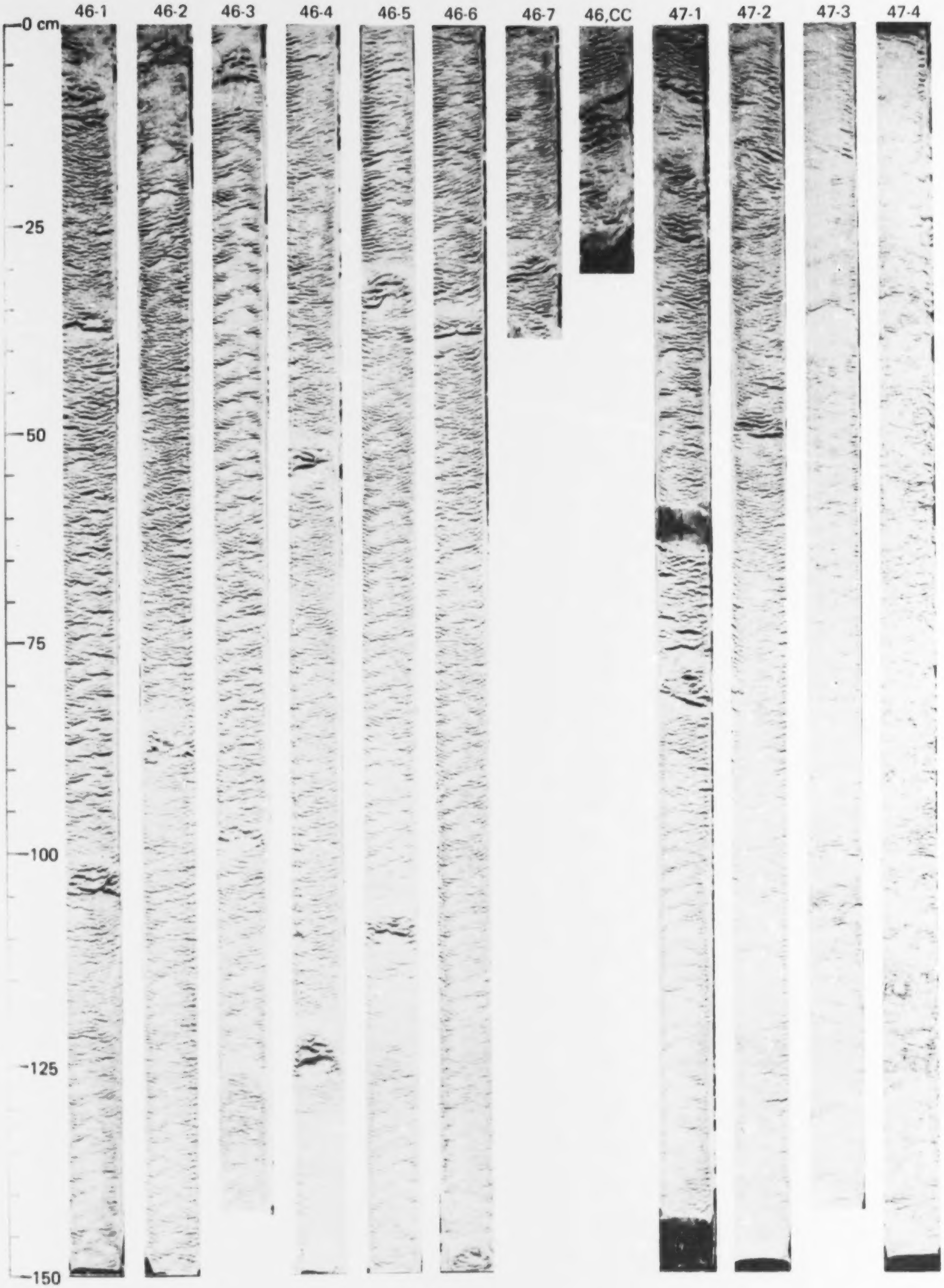
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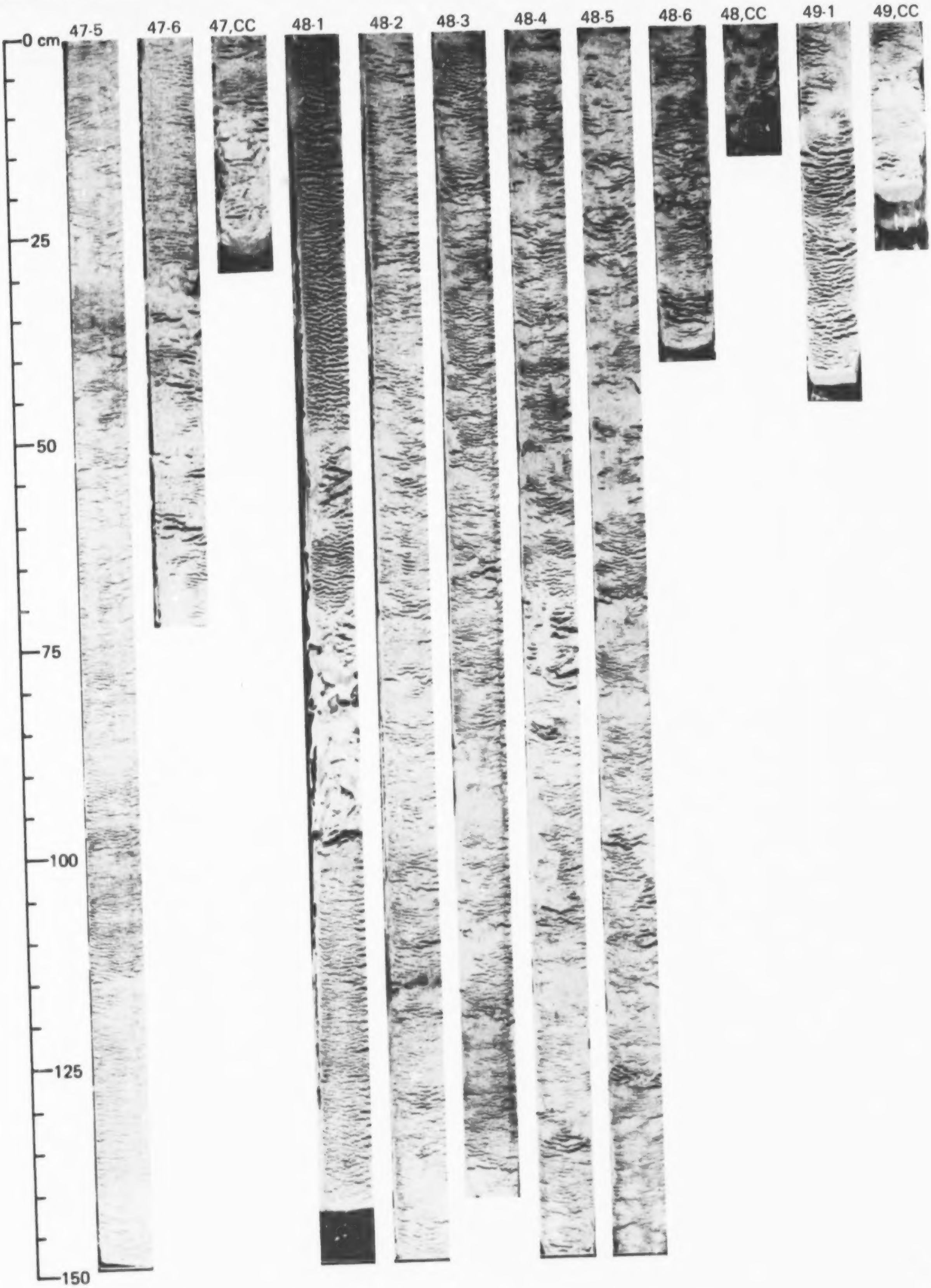
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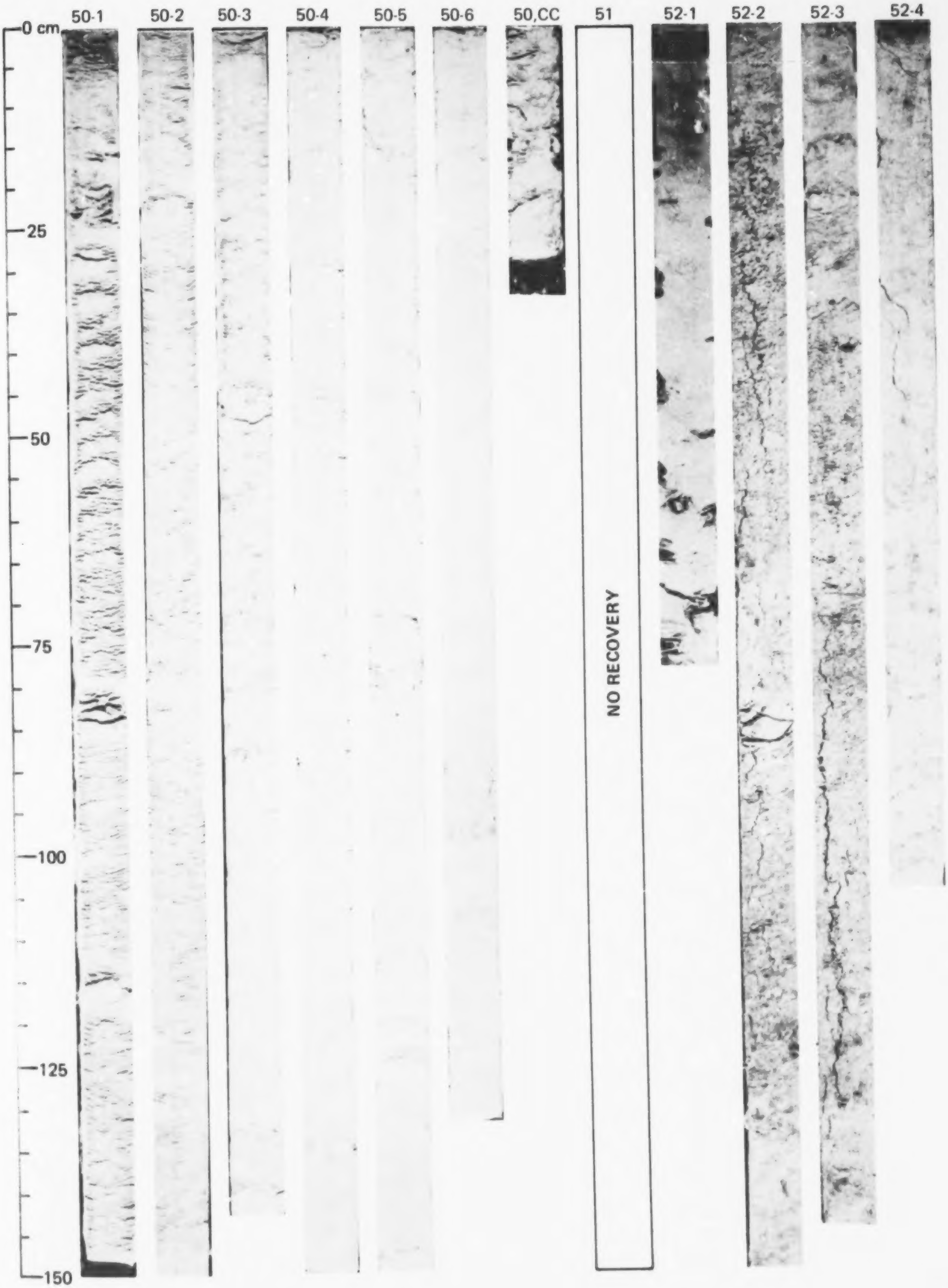
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125
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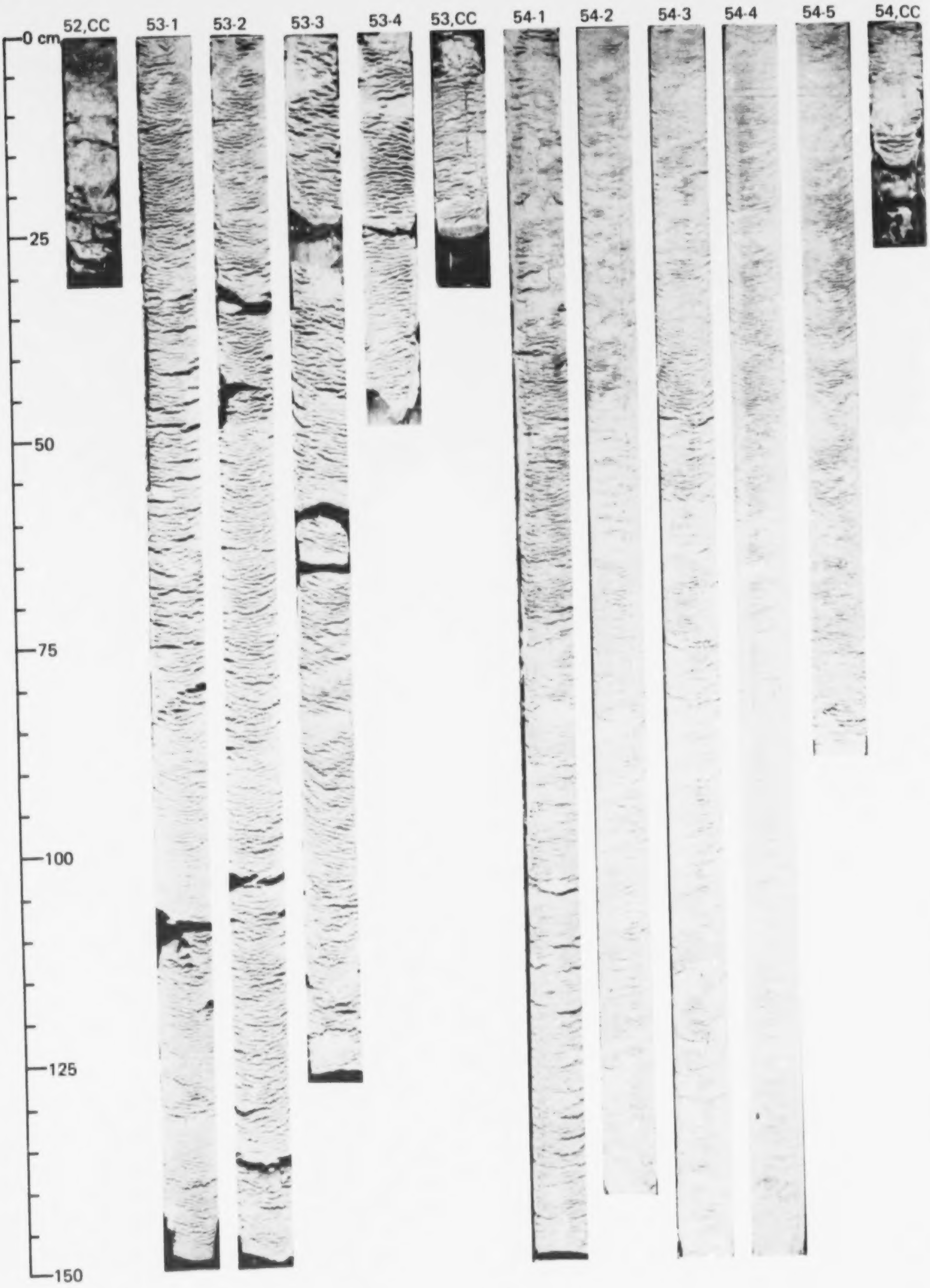
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53-2
53-3
53-4
53,CC
54-1
54-2
54-3
54-4
54-5
54,CC
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75
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125
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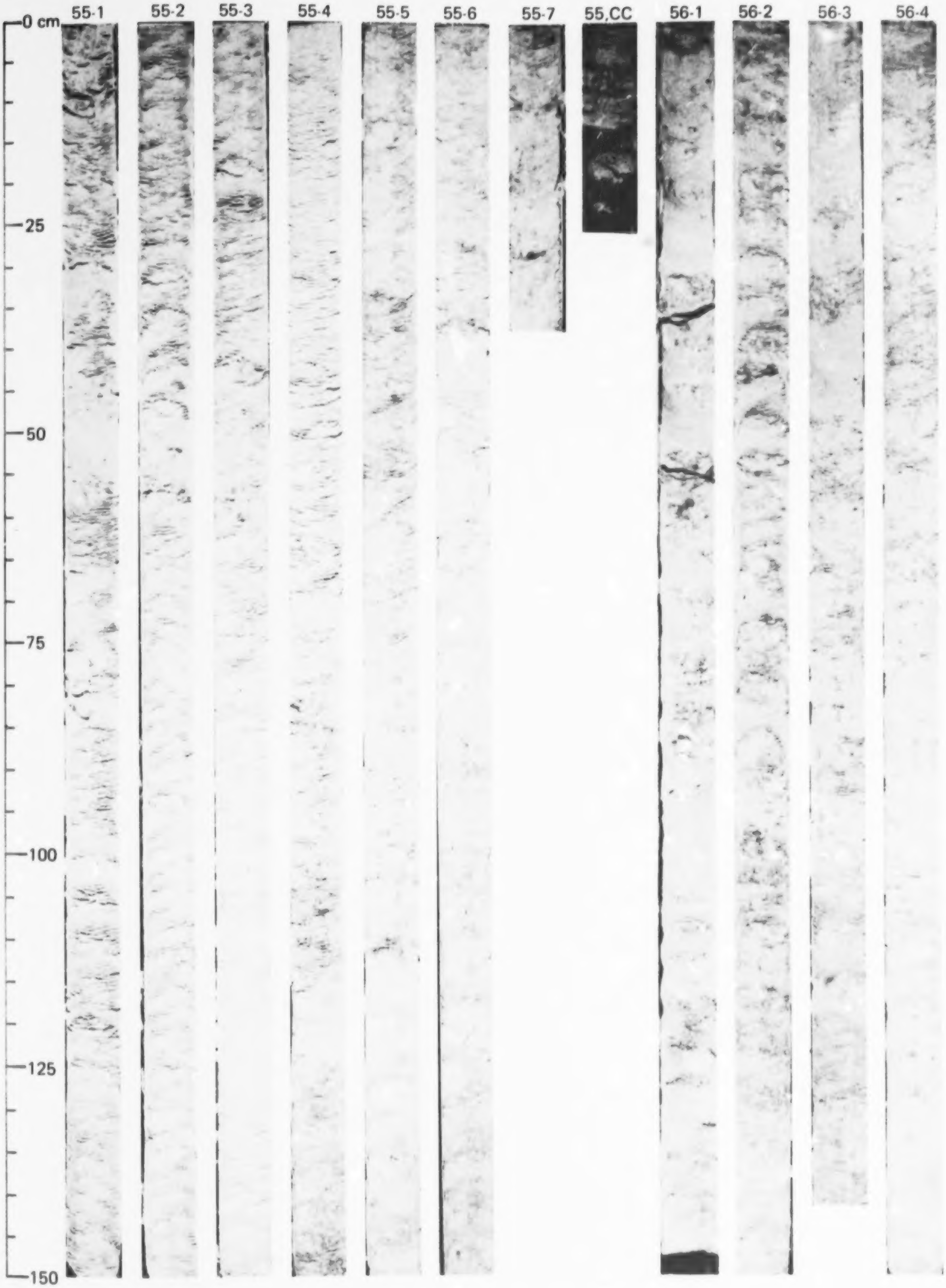
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55-4
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56-3
56-4
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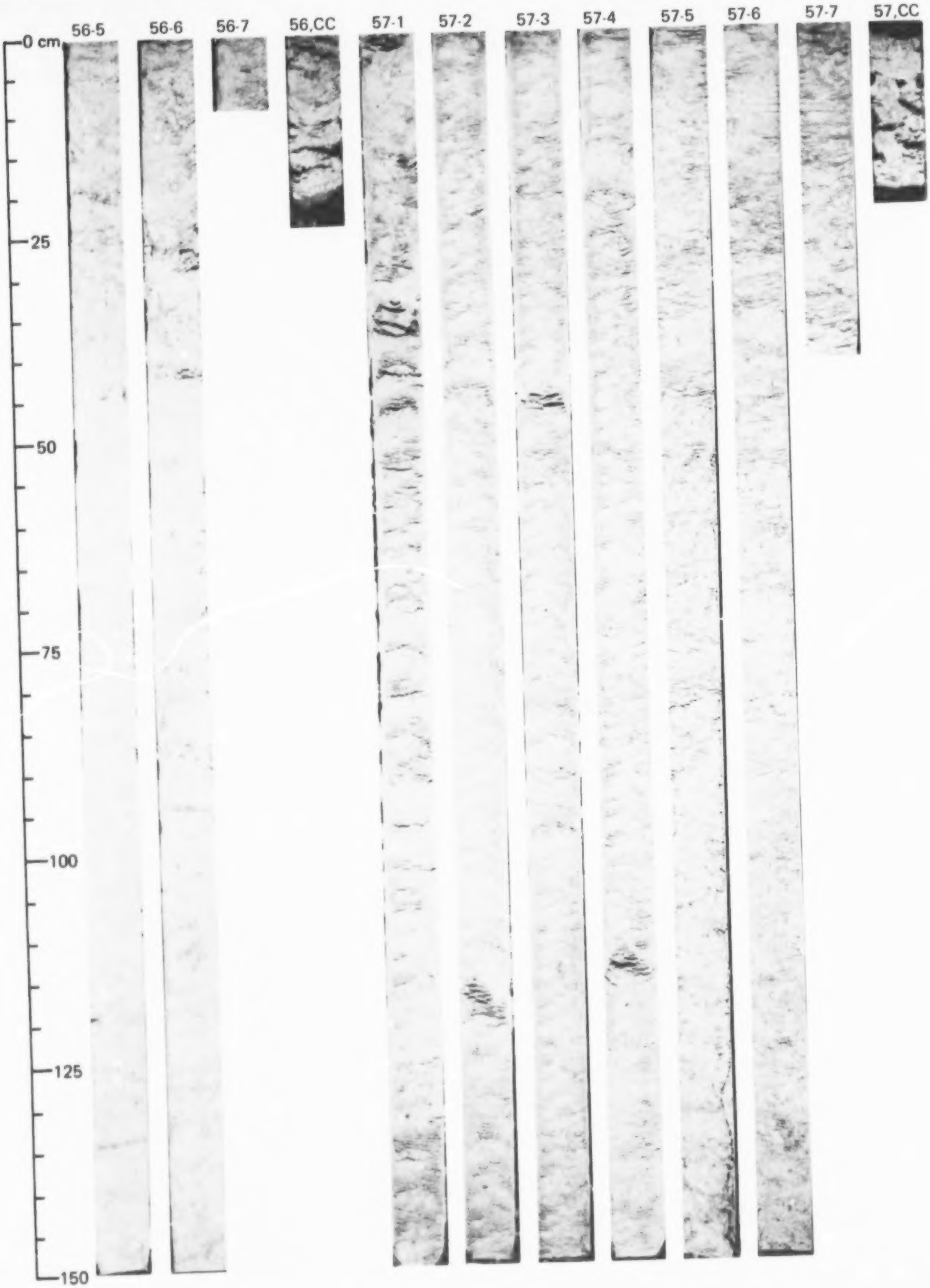
56-5
56-6
56-7
56,CC
57-1
57-2
57-3
57-4
57-5
57-6
57-7
57,CC
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125
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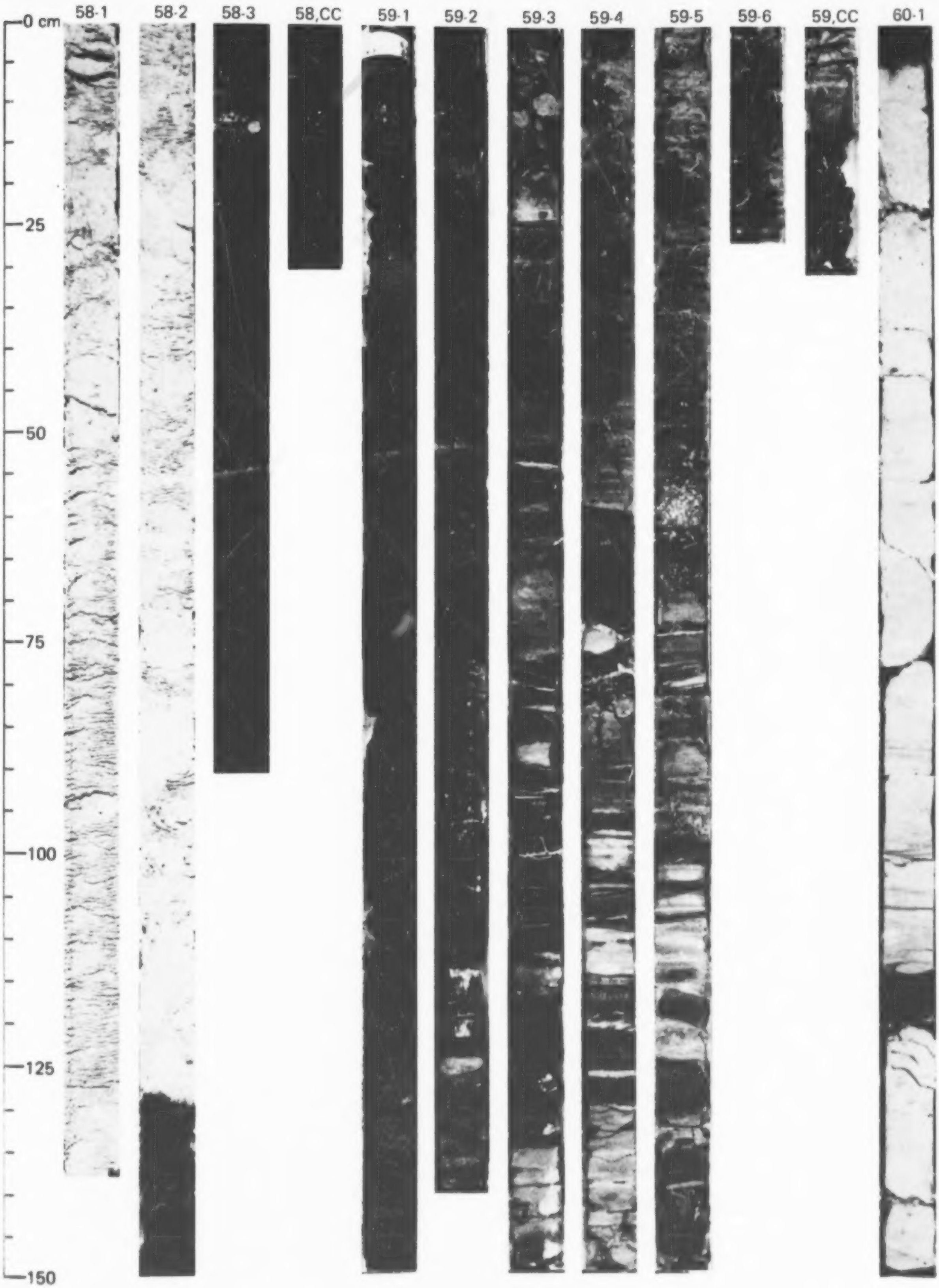
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58,CC
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59-2
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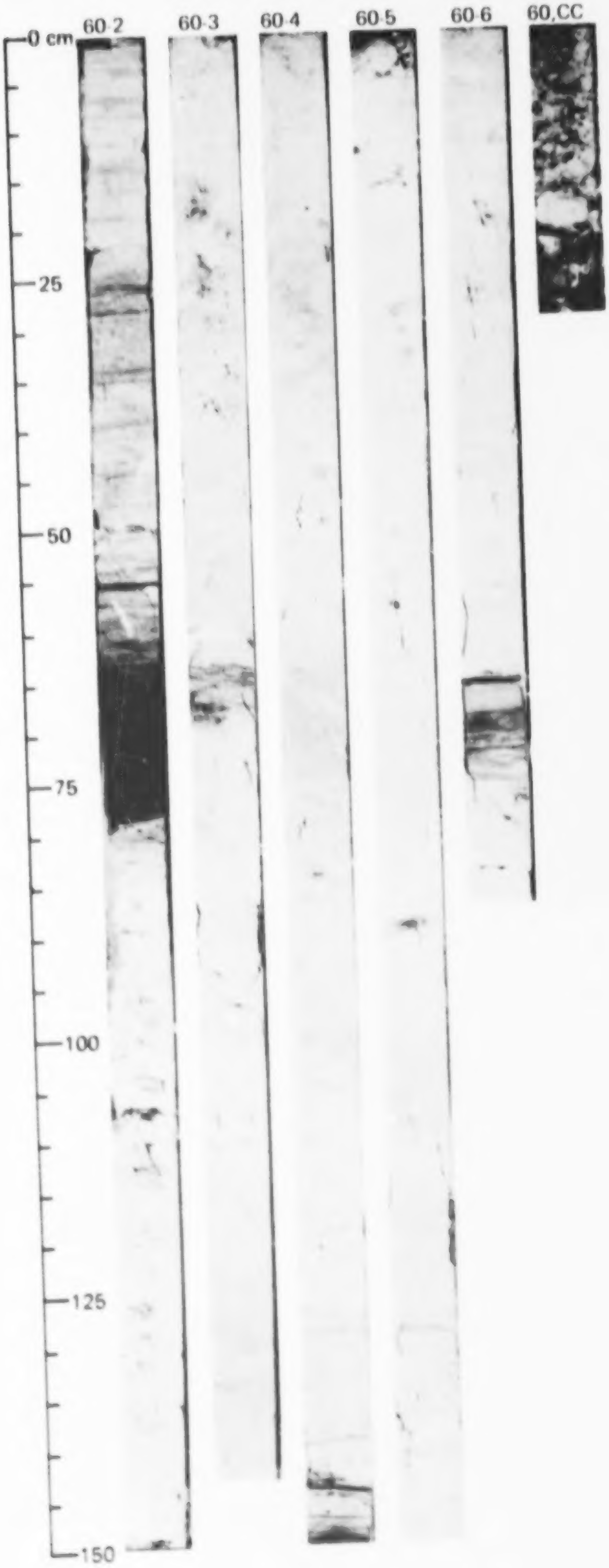
59-5
59-6
59,CC
60-1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60-6
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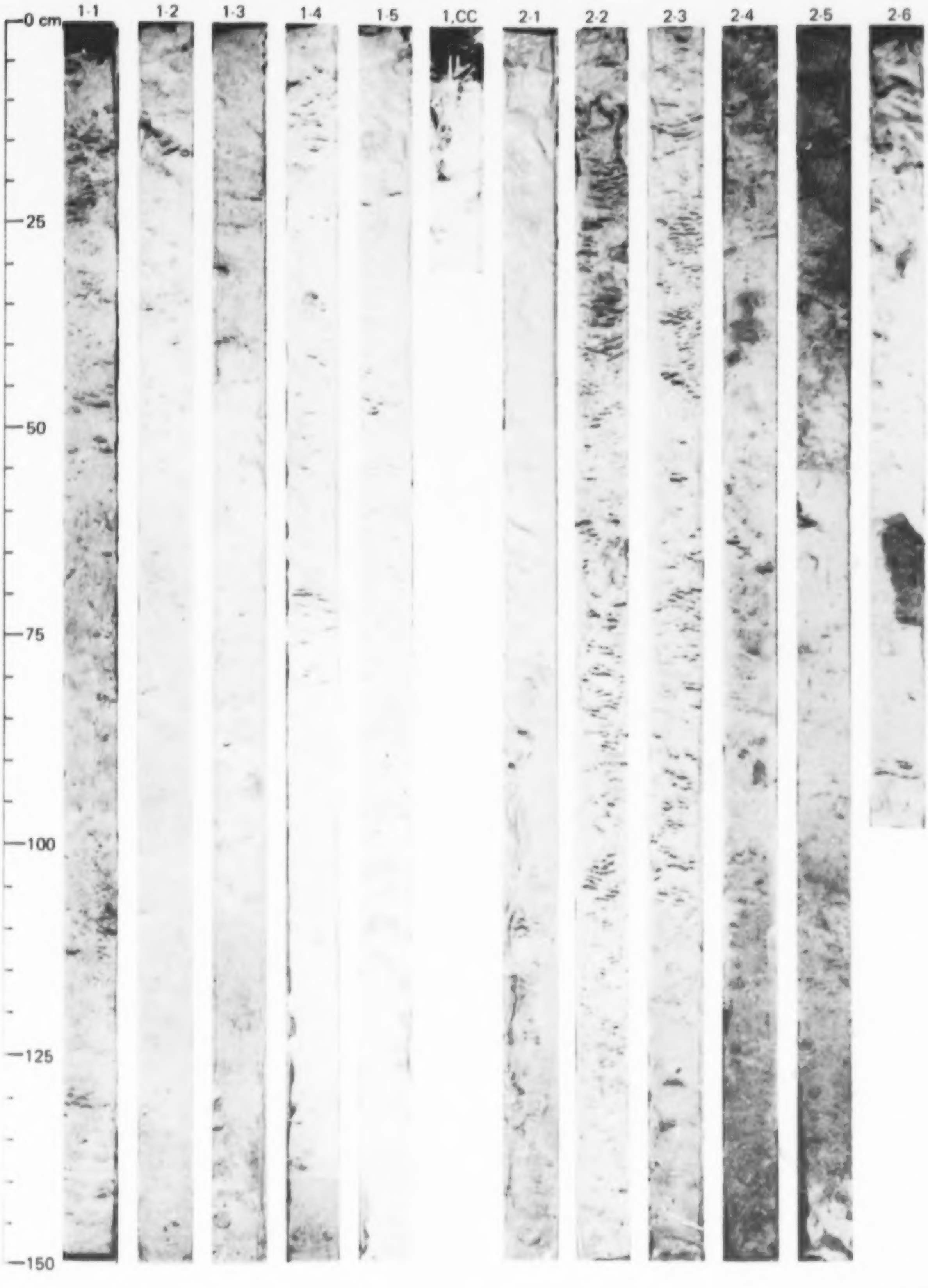
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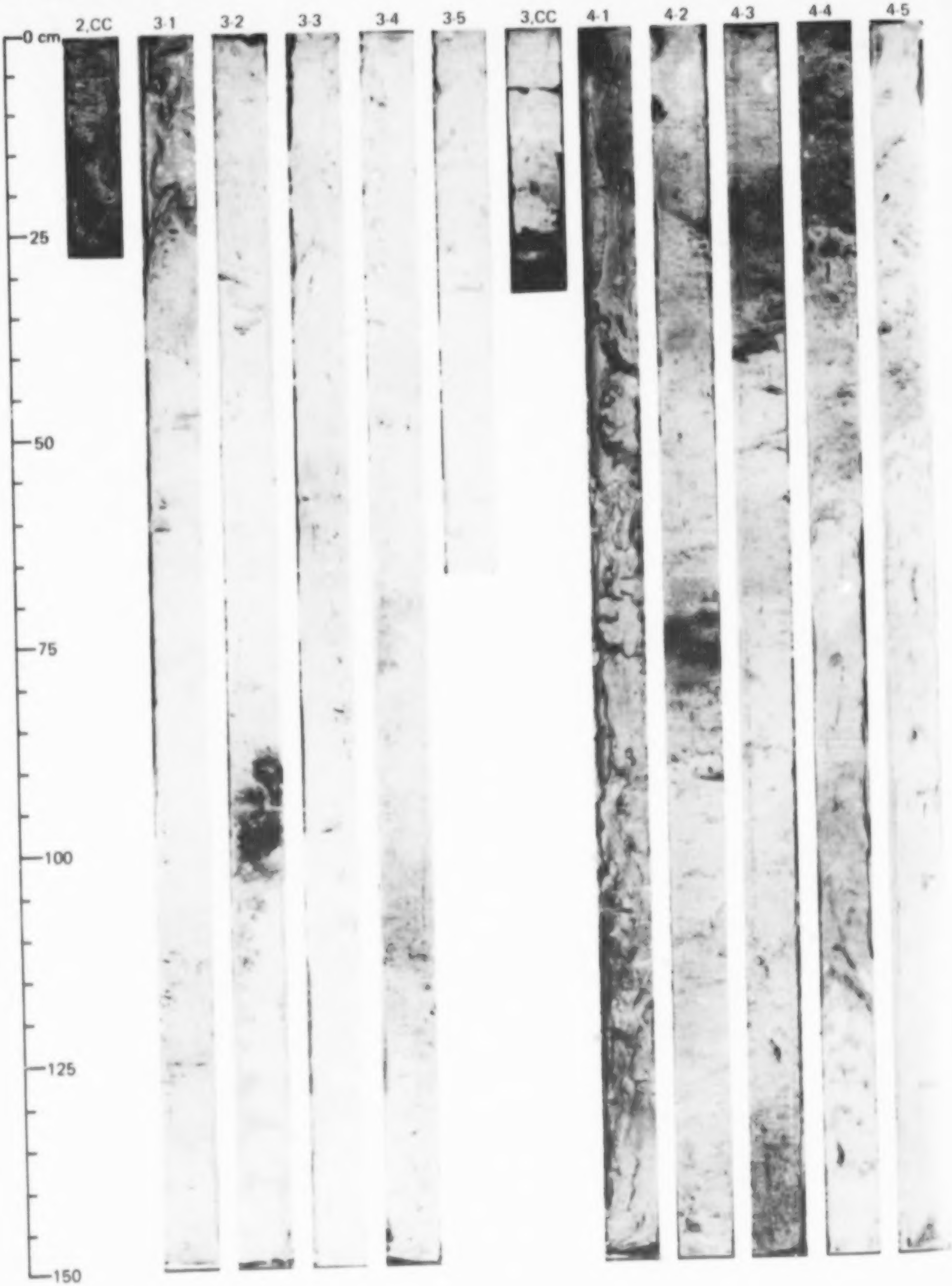
2-5
2-6


2,CC
3-1
3-2
3-3
3-4
3-5
3,CC
4-1
4-2
4-3
4-4
4-5
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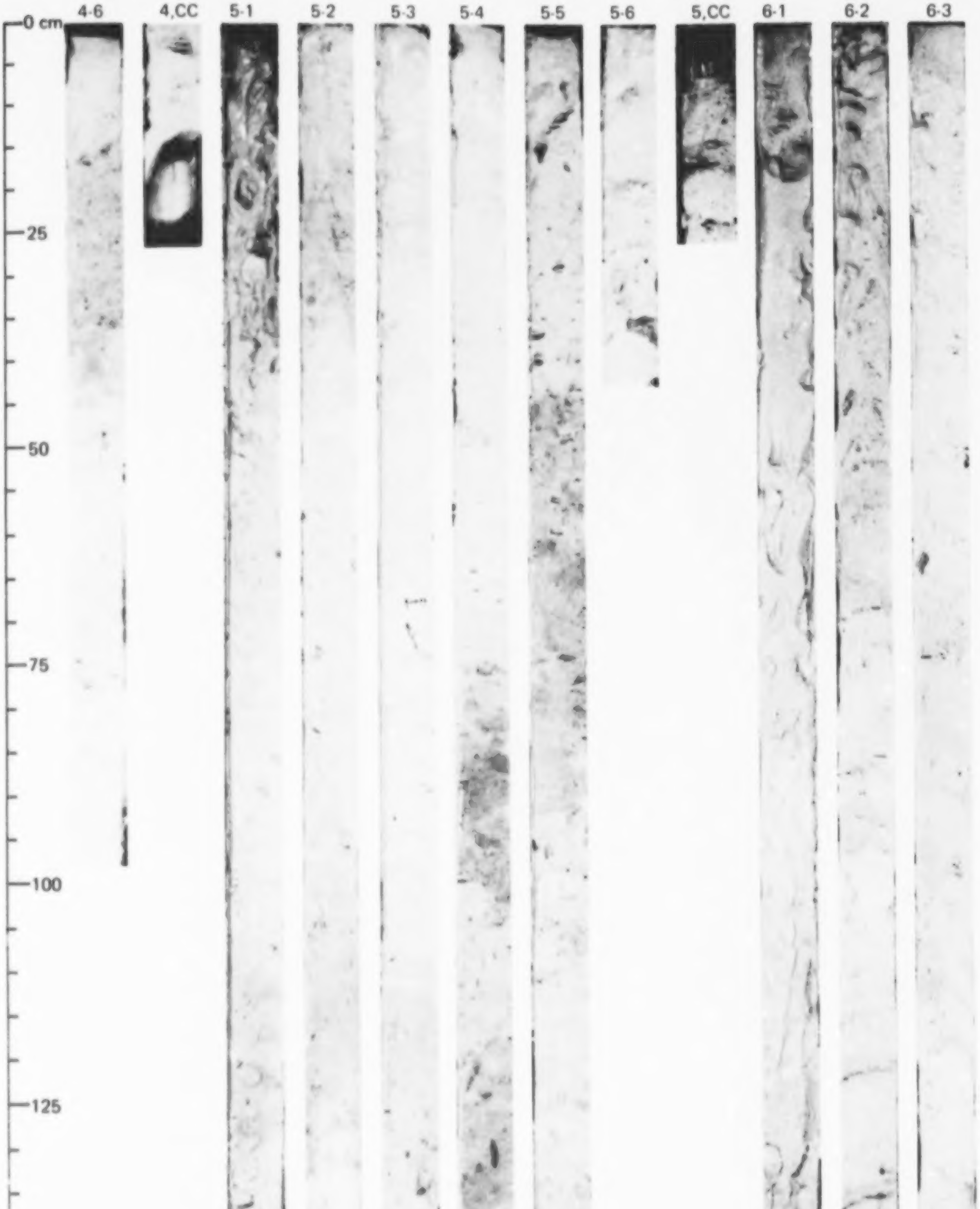
50
75
100
125
150


4-6
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5,CC
6-1
6-2
6-3
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125
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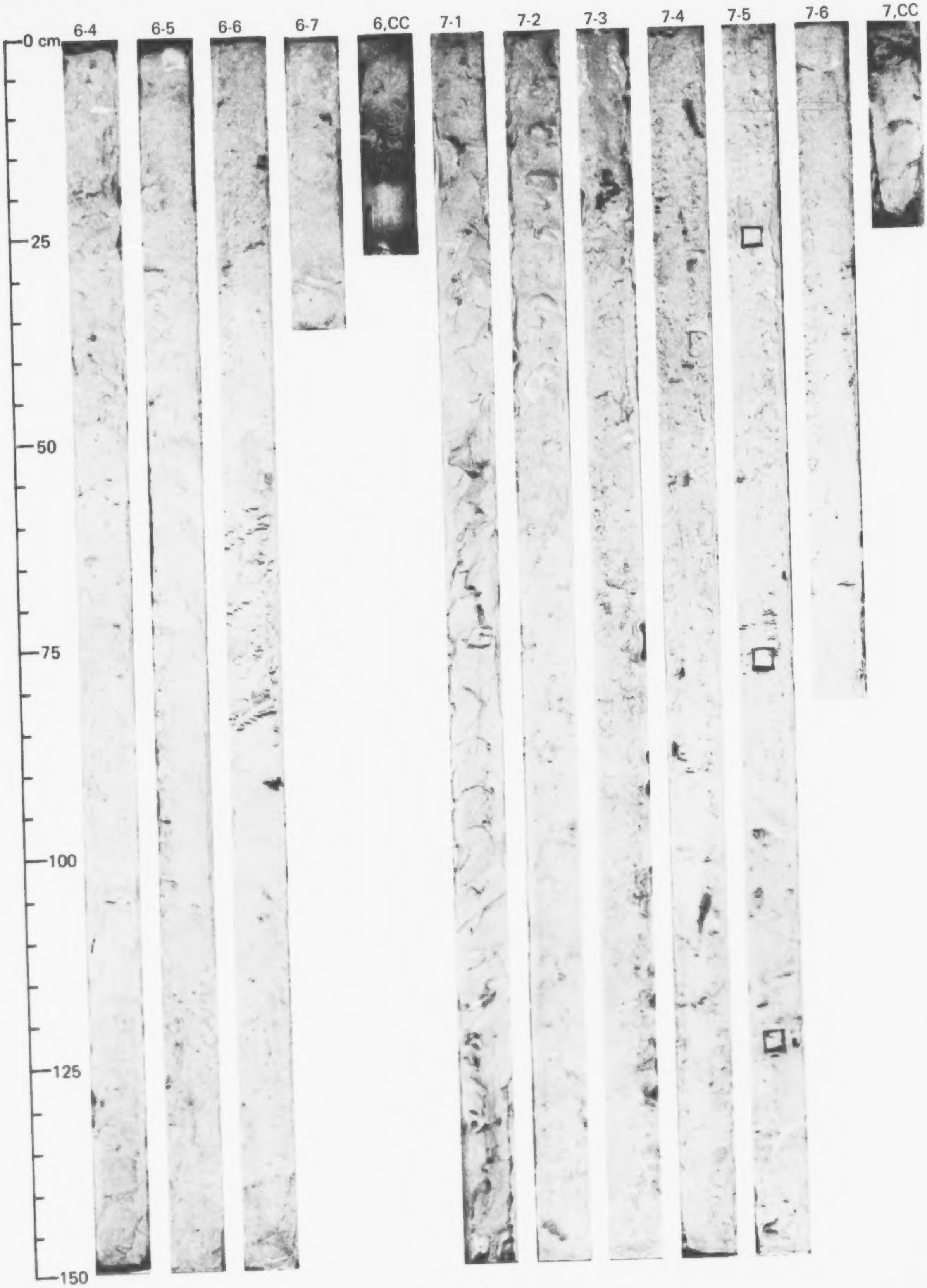
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6-7
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7-3
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7-5
7-6
7,CC
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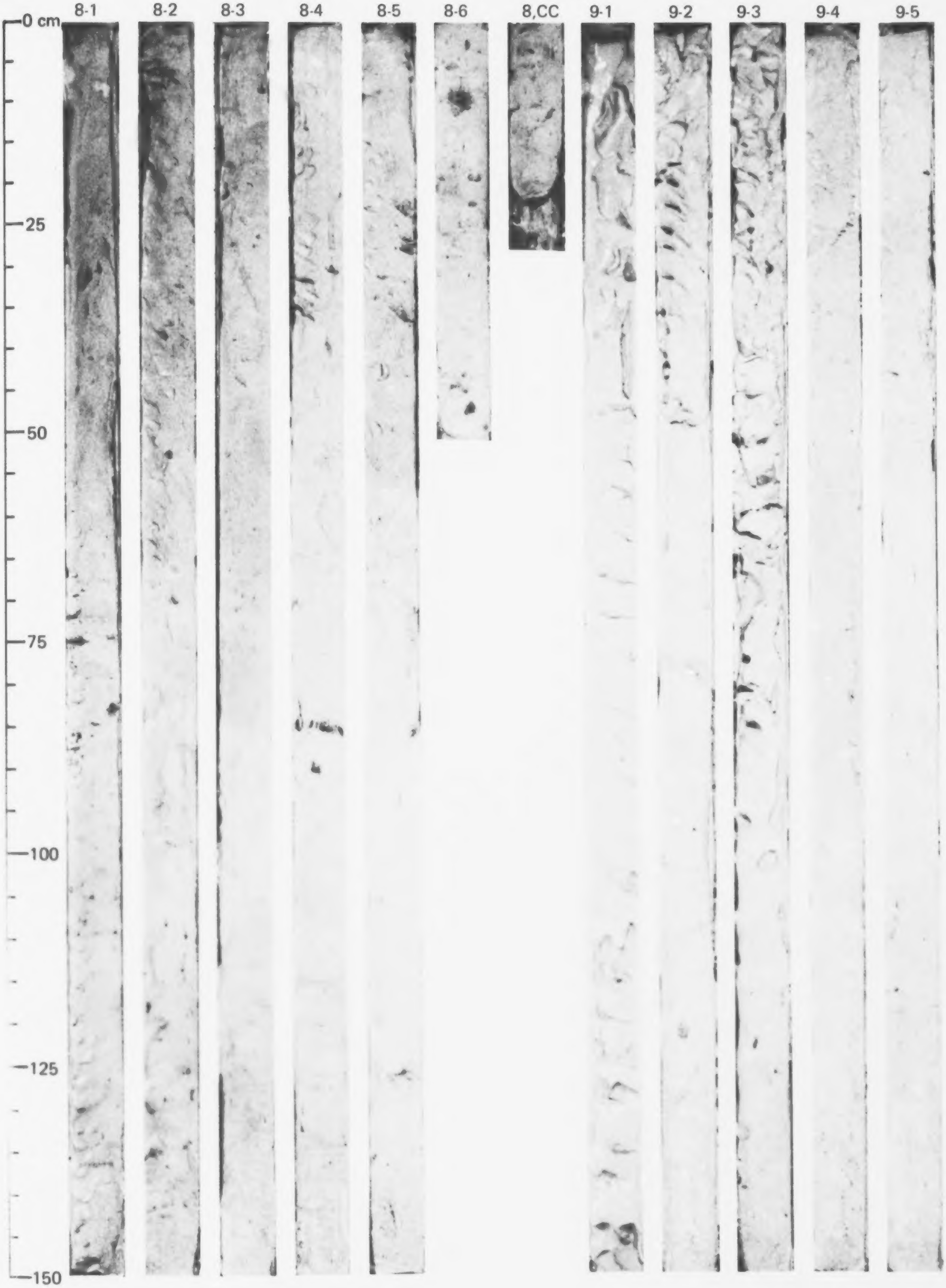
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8-6
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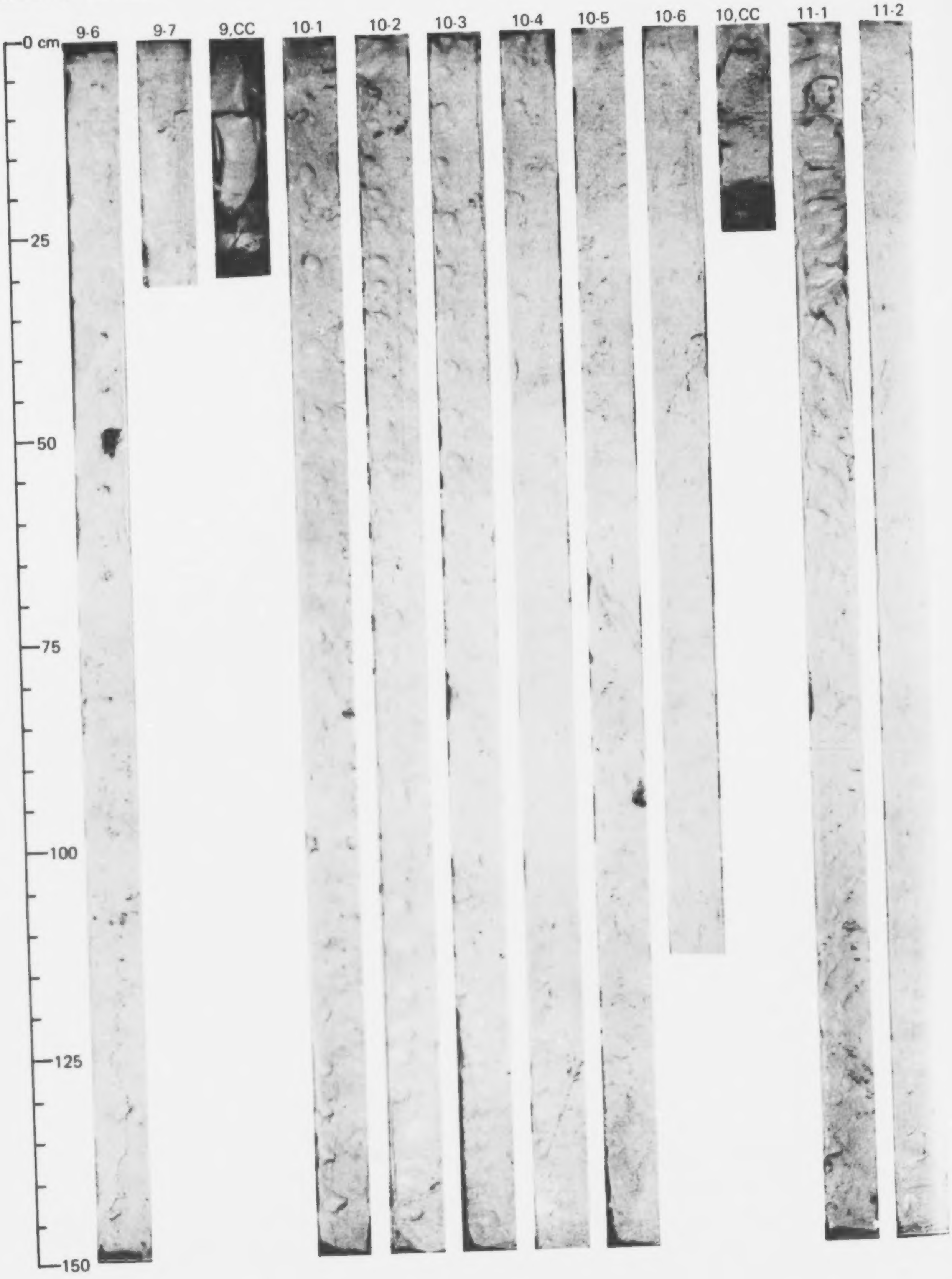
9-1
9-2
9-3
9-4
9-5

SITE 593 (HOLE 593A)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10,CC
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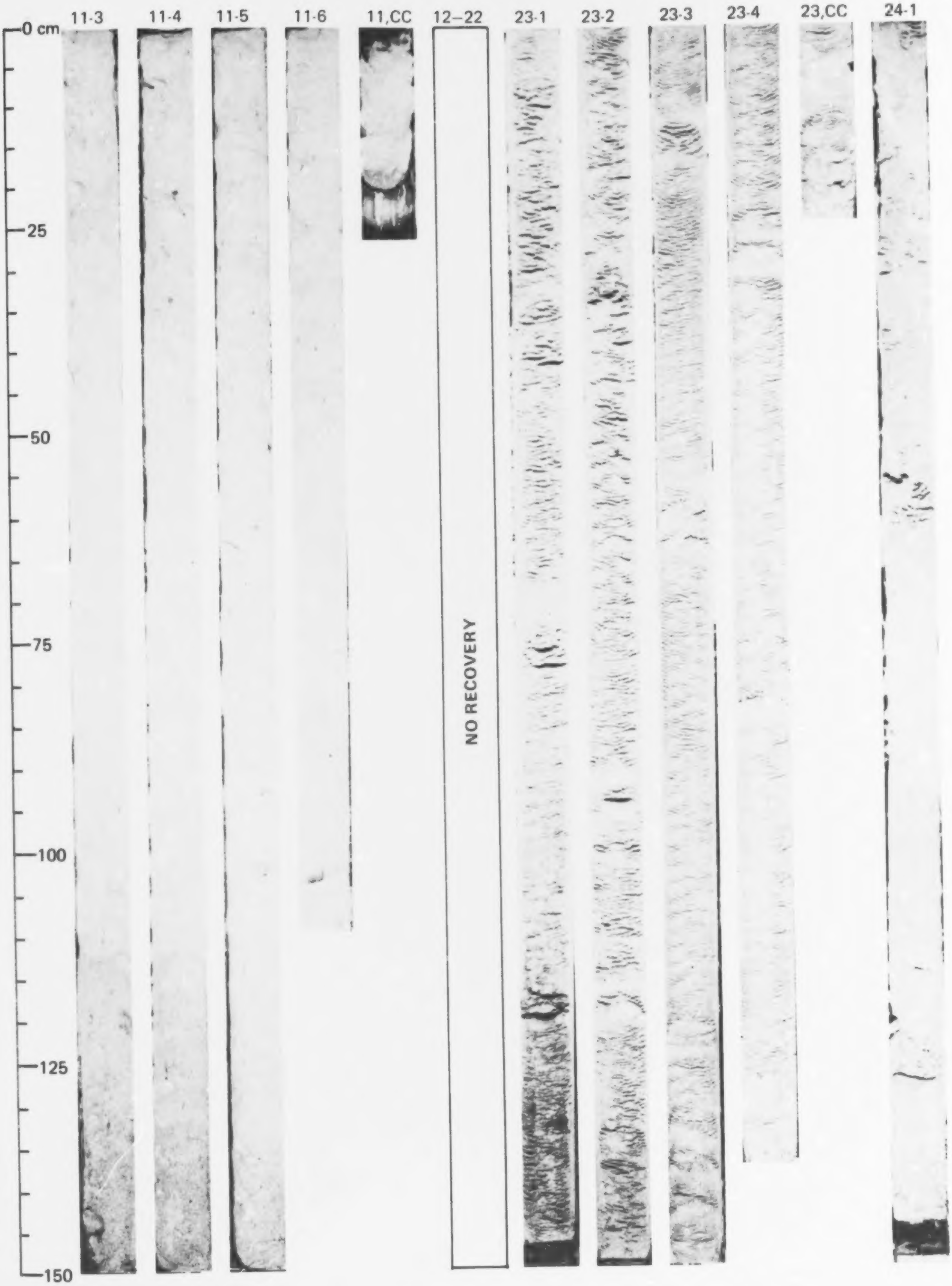
125
150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11-4
11-5
11-6
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23-1
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23-3
23-4
23,CC
24-1
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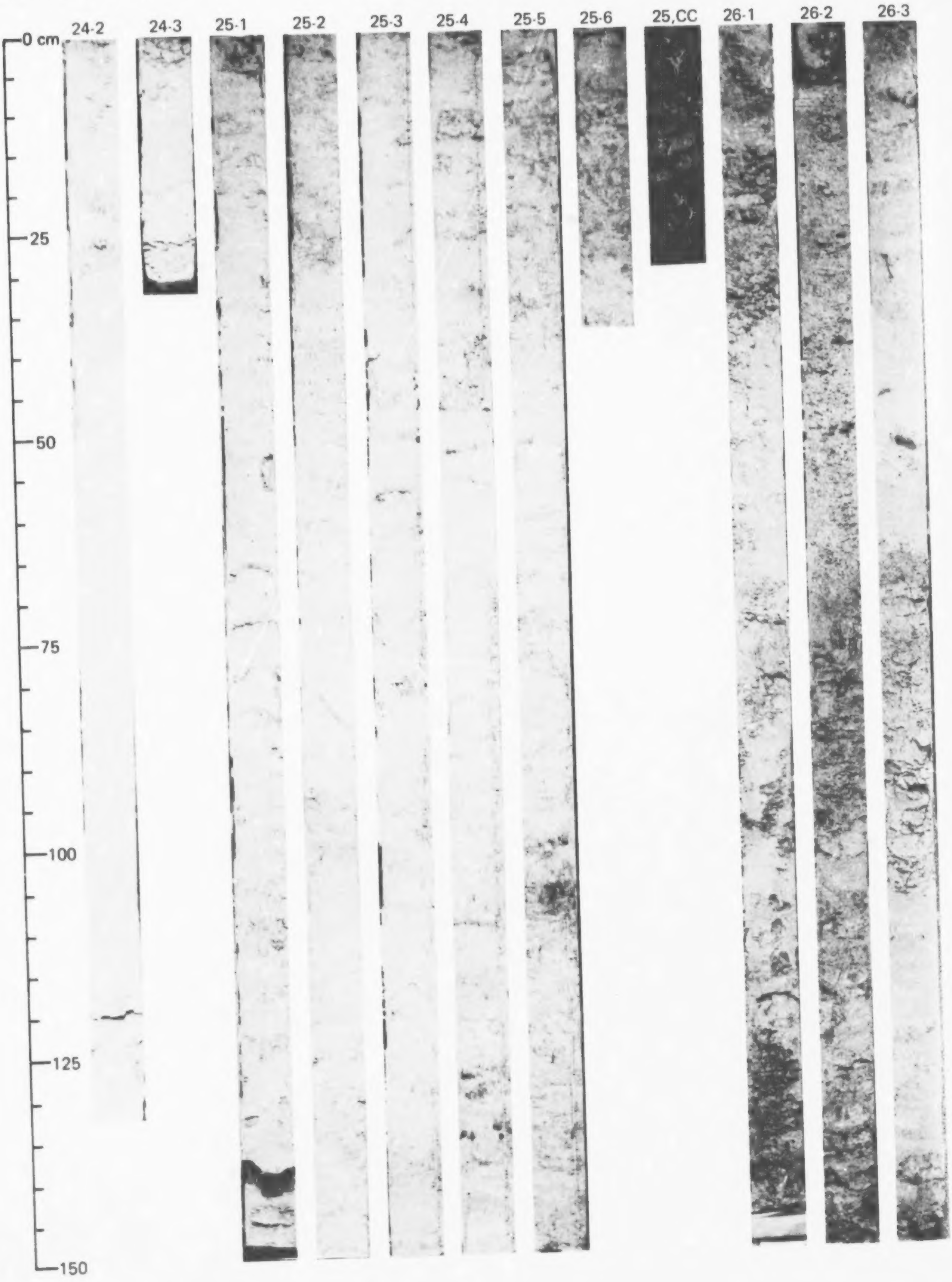
50
75
100
125
150
NO RECOVERY


24-2
24-3
25-1
25-2
25-3
25-4
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25-6
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26-1
26-2
26-3
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75
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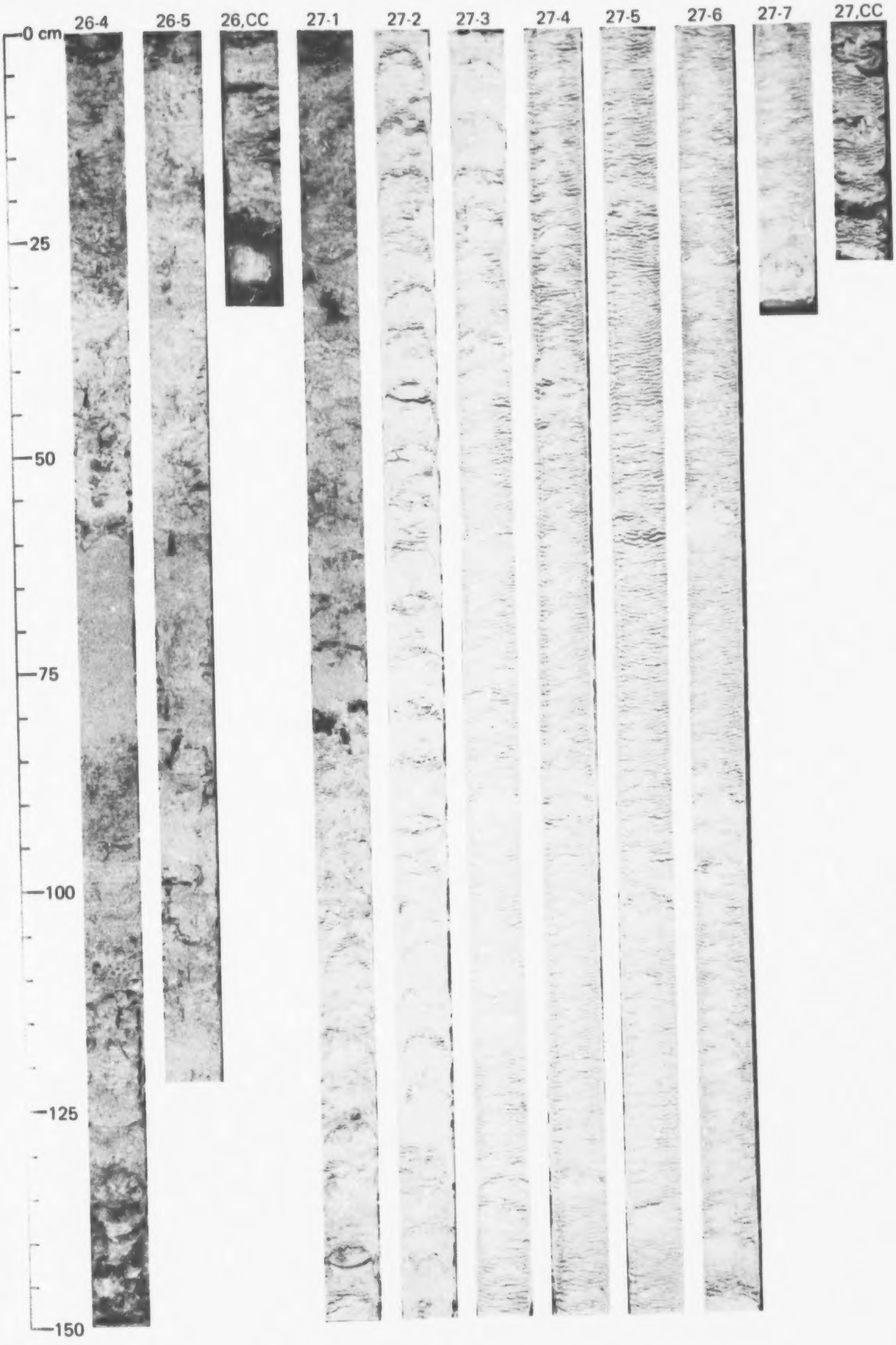
26-4
26-5
26,CC
27-1
27-2
27-3
27-4
27-5
27-6
27-7
27,CC
0 cm
25
50
75
100
125
150

10. SITE 594: CHATHAM RISE[1]

Shipboard Scientific Party[2]

HOLE 594

ate occupied: 3 January 1983

ate departed: 5 January 1983

me on hole: 52 hr.

sition: 45°31.41′S; 174°56.88′E

ater depth (sea level; corrected m, echo-sounding): 1204

ater depth (rig floor; corrected m, echo-sounding): 1214

ttom felt (m, drill pipe): 1211

netration (m): 505.1

Number of cores: 53

Total length of cored section (m): 505.1

Total core recovered (m): 299.72

Core recovery (%): 59.3

Oldest sediment cored:
Depth sub-bottom (m): 505.1
Nature: Nannofossil ooze
Age: Late early Miocene
Measured velocity (km/s): 1.646 at 487 m

Basement: Not reached

HOLE 594A

Date occupied: 6 January 1983

Date departed: 7 January 1983

Time on hole: 29 hr., 40 min.

Position: 45°31.41′S; 174°56.88′E

Water depth (sea level; corrected m, echo-sounding): 1204

Water depth (rig floor; corrected m, echo-sounding): 1214

Bottom felt (m, drill pipe): 1211

Penetration (m): 639.5

Number of cores: 26

Total length of cored section (m): 249.6

Total core recovered (m): 161.55

Core recovery (%): 64.7

Oldest sediment cored:
Depth sub-bottom (m): 639.5
Nature: Siltstones (turbidites)
Age: Miocene
Measured velocity (km/s): 2.106 at 622 m

Basement: Not reached

HOLE 594B

Date occupied: 7 January 1983

Date departed: 7 January 1983

Time on hole: 8 hr., 8 min.

Position: 45°31.41′S; 174°56.88′E

Water depth (sea level; corrected m, echo-sounding): 1204

Water depth (rig floor; corrected m, echo-sounding): 1214

Bottom felt (m, drill pipe): 1212.2

Penetration (m): 42.9

Number of cores: 5

Total length of cored section (m): 42.9

Total core recovered (m): 34.18

Core recovery (%): 79.6

Oldest sediment cored:
Depth sub-bottom (m): 42.9
Nature: Hemipelagic ooze
Age: Quaternary
Measured velocity (km/s): 2.106 at 622 m

Basement: Not reached

Principal results: Site 594 is located at the southern margin of the Chatham Rise east of the South Island of New Zealand, in a water depth of 1204 m at a position of 45°31.41′S, 174°56.88′E. The site lies in the subantarctic water mass immediately south of the Subtropical Convergence, and is the southernmost of the series of sites forming a north–south transect. It is situated in a transitional region between oceanic and terrigenous influences, thus differing from all other sites on the southwest Pacific transect.

Site 594 consists of three holes cored to a maximum sub-bottom depth of 639.5 m. Excellent core recovery was obtained from 0 to 207.5 m sub-bottom depth (Holocene to latest Miocene), using the HPC to about 130 m in Holes 594 and 594A. The remaining section was rather poorly recovered using the XCB.

The section from the latest early Miocene to the Holocene contains unconformities in the middle late Miocene, over the Miocene/Pliocene boundary, in the middle Pliocene, and in the latest

---

[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

[2] James P. Kennett (Co-Chief Scientist), Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882; Christopher C. von der Borch (Co-Chief Scientist), School of Earth Sciences, Flinders University of South Australia, Bedford Park, South Aus- lia 5042; Paul A. Baker, Department of Geology, Duke University, Durham, NC 27708; arles E. Barton, Graduate School of Oceanography, University of Rhode Island, Narra- nsett, RI 02882 (present address: Bureau of Mineral Resources, Geology, and Geophysics, Box 378, Canberra, A.C.T., Australia); Anne Boersma, Microclimates, Inc., 404 RR1, y Point, NY 10980; Jean-Pierre Caulet, Laboratoire de Géologie, Muséum National d'His- Naturelle, 43 Rue Buffon, 75005, Paris, France; Walter C. Dudley, Jr., Natural Sciences sion, College of Arts and Sciences, University of Hawaii at Hilo, Hilo, Hawaii 96720; es V. Gardner, Pacific-Arctic Branch of Marine Geology, U.S. Geological Survey, 345 dlefield Rd., Menlo Park, CA 94025; D. Graham Jenkins, Department of Earth Sciences, n University, Walton Hall, Milton Keynes, MK7 6AA, Buckinghamshire, United King- William H. Lohman, Marathon Oil Co., Denver Research Center, P.O. Box 269, Little- CO 80160; Erlend Martini, Geologisch-Paläontologisches Institut, Johann-Wolfgang- he Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic ermany; Russell B. Merrill, Deep Sea Drilling Project A031, Scripps Institution of Ocean- phy, La Jolla, CA 92093 (present address: Ocean Drilling Project, Texas A&M University, ge Station, TX 77843-3469); Roger Morin, Department of Earth and Planetary Sci- Massachusetts Institute of Technology, Cambridge, MA 02139 (present address: U.S. ogical Survey, Denver Federal Center, Denver, CO 80225); Campbell S. Nelson, Depart- of Earth Sciences, University of Waikato, Private Bag, Hamilton, New Zealand; Chris- Robert, Laboratoire de Géologie Marine, Centre Universitaire de Luminy, Case 901, 8 Marseille Cedex 09, France; M. S. Srinivasan, Department of Geology, Banaras Hindu ersity, Varanasi 221 005, India; Rudiger Stein, Geologisch-Paläontologisches Institut, ersität Kiel, 2300 Kiel, Federal Republic of Germany (present address: Institute of Petro- and Organic Geochemistry (ICH-5), Kernforschungslage Jülich GmbH, P.O. Box 1913, Jülich, Federal Republic of Germany); Akira Takeuchi, Department of Earth Sciences, ity of Science, Toyama University, Gohuku 3190, Toyama 930, Japan.

Pliocene. A paleomagnetic stratigraphy has been identified down to the late part of the Gauss Chron (about 2.5 m.y. ago).

The sequences are assigned to two lithostratigraphic units, the lower one of which is subdivided into two subunits.

Unit I, of earliest Pliocene to Quaternary age, consists of an alternating sequence of pelagic and hemipelagic lithofacies, generally defined by bluish gray and greenish gray sediment, respectively.

The pelagic lithofacies consists mainly of blue gray foraminifer-bearing nannofossil ooze, foraminifer- and clay-bearing nannofossil ooze, or foraminifer-bearing clayey nannofossil ooze.

The hemipelagic lithofacies consists of a variety of sediment intergrades between a clay- and silt-bearing nannofossil ooze and a nannofossil-bearing clayey silt; this greenish-gray lithofacies commonly diatom- and sponge spicule-bearing, rarely foraminifer-bearing.

The contact between Units I and II is gradational over several meters, but is recognized by the change from the interbedded pelagic and hemipelagic facies of Unit I to a pelagic facies of Unit II. Unit II, of late early Miocene to earliest Pliocene age, is mainly a foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk). The ooze/chalk transition occurs at about 66 m in Hole 594.

Subunit IIA, of middle Miocene to earliest Pliocene age, is a light gray foraminifer-bearing nannofossil ooze that grades down into a nannofossil ooze and continues to about 466 m sub-bottom depth in Hole 594.

Subunit IIB, of late early to middle Miocene age, is a light gray nannofossil chalk with occasional interbeds of olive gray silt-bearing clayey nannofossil chalk below 534 m sub-bottom in Hole 594A; these are interpreted as turbidite layers.

Site 594 was well located to monitor the changing influences of terrigenous and pelagic sequences through the Neogene. The first influx of hemipelagic sequences during the late Neogene occurred about 6 m.y. ago, replacing a completely calcareous pelagic facies containing no significant terrigenous components. This dates the beginning of the Kaikoura Orogeny, when the New Zealand (southern) Alps were uplifted along the Alpine Fault.

Dated much earlier, about 17 m.y. ago, was a tectonic episode evidenced by the deposition of the clay turbidites of Subunit IIB. The upper part of the turbidite sequence forms a distinctive reflector which shows at about 600 m sub-bottom in the seismic profiles. The deposition of the turbidite sequence possibly coincided with major strike-slip motion along the Alpine Fault sector of the Indian/Pacific plate boundary. The volcanic ash layer sequences at this and other sites are probably also related to the associated volcanic activity. The two tectonic episodes were separated by about 10 m.y. of vertical tectonic quiescence during which pelagic calcareous sediments (Subunit IIA) were deposited.

Site 594 has much paleoceanographic potential. There is a useful biostratigraphic sequence of subantarctic elements from the middle Miocene to the Holocene, although this is broken in places by unconformities. Both calcareous and siliceous microfossil groups are well represented. The calcareous nannoplankton are typical cold-water assemblages and largely lack the warm-water forms so useful in biostratigraphic zonation. Considerable microfossil reworking, particularly of foraminifers, was associated with the early middle Miocene turbidites.

The latest Miocene to Holocene sequence of oscillations between dark hemipelagic and lighter pelagic biogenic sediments is climatically related. The pelagic episodes mark climatic warmings and high sea levels (interglacials). These have little biosiliceous sediment, less calcareous dissolution, and warmer-water planktonic foraminifer faunas. The hemipelagics mark cooler (glacial) episodes when low stands of sea level led to major sediment bypassing over the continental shelves and to the deposition of terrigenous materials in the basins surrounding New Zealand. These episodes exhibit cold planktonic foraminiferal faunas, rich siliceous microfossil assemblages, and much carbonate dissolution. Intergrades occur between the two extremes. Twenty-five major hemipelagic depositional episodes are recorded in the upper 200 m (6 m.y. ago to ?), although unconformities represent part of this sequence. The oldest hemipelagic episode coincides with the well-known Kapitean (Messinian) regression.

A distinct increase in radiolarian abundances occurs during the late Miocene. This may have been in response to the important paleoceanographic changes which may have led to the developmen of the Subtropical Convergence.

BACKGROUND AND OBJECTIVES

Southern Chatham Rise

Site 594 is located at the southern margin of the Cha ham Rise east of the South Island of New Zealand (Fi 1). The site lies in the subantarctic water mass immed ately south of the Subtropical Convergence, and is th southernmost of a series of sites forming a north–sout transect. It is situated in a transitional region betwee oceanic and terrigenous influences, thus differing fro all other sites on the transect. It is located on a relativel flat, smooth seafloor, underlain by what appears to be simple seismic stratigraphy of parallel reflectors (Fig. 2

The primary scientific objectives for Site 594 were obtain a high-resolution stratigraphic sequence from th Quaternary to the late Paleogene using the hydraulic pi ton corer (HPC) and extended core barrel (XCB). Mult disciplinary studies on the cores were expected to assis in understanding middle to late Cenozoic paleoceanographic and paleoclimatic history, biogenic evolution, and diagenesis. In addition, the site lies downwind from New Zealand and was expected to contain a valuable record of volcanism in the form of tephra layers. The location of Site 594 in subantarctic waters provided an additional opportunity, not available in higher-latitude sites of the transect, to study what should be distinct oscillations between glacial and interglacial episodes. Griggs et al. (1983), in studies of the late Quaternary using conventional piston cores, demonstrated that such oscillations are well represented in the region. Interglacial episodes are marked by a rich planktonic foraminiferal assemblage of southern temperate character, glacial episodes by a planktonic foraminiferal assemblage of distinctly subantarctic character, accompanied by noticeable abun-

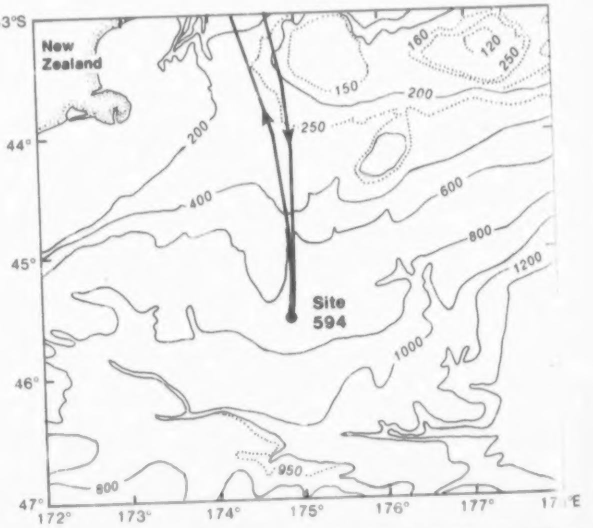

Figure 1. Regional bathymetry (fathoms) around Site 594, after Mammerickx et al. (1974). *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

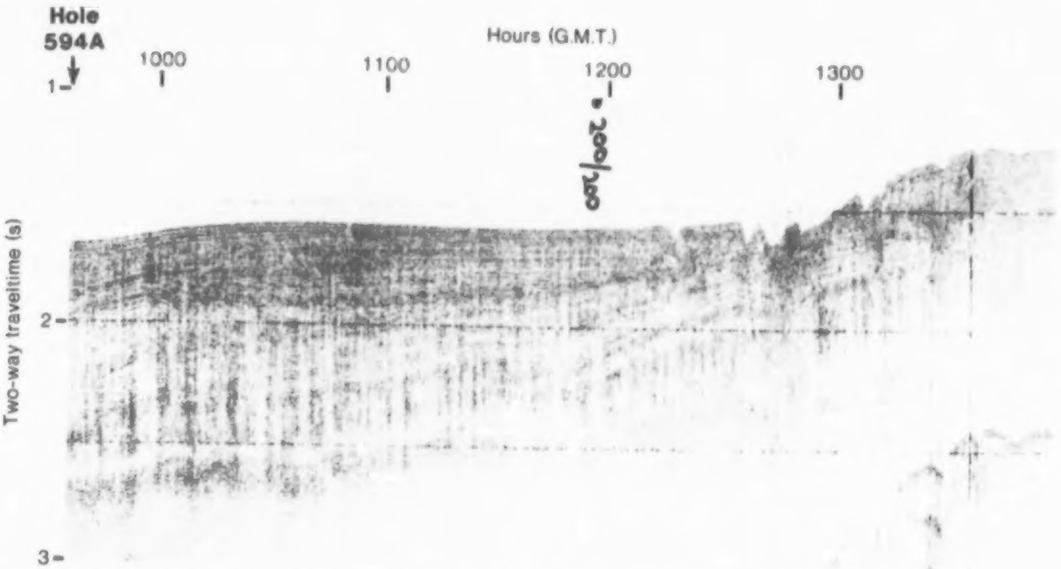

Figure 2. Water gun seismic profile (*Glomar Challenger* near Site 594; bandpass filter 40–160 Hz).

dances of mica and siliceous biogenic components including radiolarians, diatoms, and spicules, and showing clear evidence of dissolution. Site 594 was, therefore, expected to supply data on carbonate cycles and carbonate dissolution. The relative abundance of siliceous components was expected to allow studies of the biostratigraphy and paleoenvironments of these organisms, which occur only in minor amounts in the more northerly sites of the Leg 90 transect. Finally, it was hoped that the site would contain evidence of ice-rafting in the late Neogene, since ice-rafted erratics from Antarctica occur on the Chatham rise (Cullen, 1976).

OPERATIONS

Site 593 to Site 594

The transit between the final two sites provided some of the most pleasant weather and the finest scenery of the voyage. From Site 593 northwest of New Zealand the ship sailed through Cook Strait between New Zealand's North and South Islands and then south to Site 594 close to the Chatham Rise. The site was approached directly along the *Eltanin* 43 survey line and the beacon was dropped at 1449 hr., 3 January, on the basis of a good seismic profile. The 603.9-mi. trip was completed in 2 days, 12.6 hr., at an average speed of 10.0 knots.

Site 594 (SW-1): Chatham Rise and Bounty Trough

The PDR depth was questionable since the location of the site was almost exactly on the border between two adjacent watermass areas listed in Matthews's *Tables*. The combination variable length (VL) HPC/XCB bottom-hole assembly was made up and run to 1208.1 m for the first mudline attempt and a successful core with 5.95 m recovery was achieved (Table 1); thus the water depth was set at 1211.8 m. Later inspection of the first core showed it to be unusually firm and some suspicion was raised as to whether or not it contained the actual mudline.

In some upper sections of the piston coring sequence, recovery was poor because the core catcher failed, but the problem was rectified by Core 594-11. Piston coring quickly reached its limit with a mangled core liner and a barrel requiring to be washed over at Core 14. The XCB was then rigged and deployed and immediately cut a full core of exceptionally undisturbed quality. More XCB cores followed as the formation changed from firm blue gray hemipelagic sediment to primarily pelagic, with ooze beginning at about 210 m BSF. At 300 m a strong siliceous element began to emerge and core recovery fell off correspondingly.

Problems with the XCB latch continued to be a mild nuisance and resulted in little or no recovery in Cores 17, 22, 32, and 33.

As coring approached 500 m BSF, the weather began to deteriorate rapidly. Fifteen-foot swells and 40–50 knot winds plus a threatening weather prognosis left no choice but to pull the pipe in the interest of safety and terminate the hole. The pipe trip was completed successfully and the bit arrived on deck at 2035 hr., 5 January.

After a 9.5-hr. wait, the weather had improved noticeably. This and more recent weather charts showed that the severe prognosis chart received earlier had been badly in error. Therefore, starting at 0100 hr., 6 January, the pipe was again run in to take the repeat piston core sequence, to use the XCB to spot-core those intervals lost in the initial hole, and to attempt to continue from the termination point of Hole 594 to reach the scientific objectives somewhere between 500 and 800 m BSF.

Hole 594A

The same BHA was run and the hole was spudded at 0435 hr., 6 January. The bit was quickly washed to 41.3 m BSF to help bury the bumper subs as soon as possible,

Table 1. Coring summary, Site 594.

Core No.	Date (Jan 1983)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 594							
1	3	1950	1211.8-1217.7	0.0-5.9	5.9	5.95	100+
2	3	2130	1217.7-1227.3	5.9-15.5	9.6	8.87	92.3
3	3	2230	1227.3-1236.9	15.5-25.1	9.6	9.34	97.3
4	3	2330	1236.9-1246.5	25.1-34.7	9.6	8.84	92.0
5	4	0000	1246.5-1256.1	34.7-44.3	9.6	9.60	100
6	4	0045	1256.1-1265.3	44.3-53.9	9.6	5.39	56.1
7	4	0130	1265.7-1275.3	53.9-63.5	9.6	2.77	22.6
8	4	0205	1275.3-1284.9	63.5-73.1	9.6	1.77	18.4
9	4	0250	1284.9-1294.5	73.1-82.7	9.6	8.99	93.6
10	4	0315	1294.5-1304.1	82.7-92.3	9.6	2.69	28.0
11	4	0400	1304.1-1313.7	92.3-101.9	9.6	9.70	100+
12	4	0445	1313.7-1323.3	101.9-111.5	9.6	7.40	77.0
13	4	0535	1323.3-1332.9	111.5-121.1	9.6	7.74	80.6
14	4	0630	1332.9-1342.5	121.1-130.7	9.6	5.74	59.8
15	4	0750	1342.5-1352.1	130.7-140.3	9.6	9.64	100+
16	4	0830	1352.1-1361.7	140.3-149.9	9.6	9.54	99.3
17	4	0915	1361.7-1371.3	149.9-159.5	9.6	0.0	0.0
18	4	1010	1371.3-1380.9	159.5-169.1	9.6	8.56	89.1
19	4	1055	1380.9-1390.5	169.1-178.7	9.6	9.55	99.4
20	4	1145	1390.5-1400.1	178.7-188.3	9.6	7.41	77.2
21	4	1235	1400.1-1409.7	188.3-197.9	9.6	9.36	97
22	4	1330	1409.7-1419.3	197.9-207.5	9.6	0.0	0
23	4	1425	1419.3-1428.9	207.5-217.1	9.6	9.20	90
24	4	1525	1428.9-1438.5	217.1-226.7	9.6	8.79	91
25	4	1555	1438.5-1448.1	226.7-236.3	9.6	8.06	84
26	4	1650	1448.1-1457.7	236.3-245.9	9.6	7.15	74
27	4	1745	1457.7-1467.3	245.9-255.5	9.6	7.62	79
28	4	1820	1467.3-1476.9	255.5-265.1	9.6	7.05	73
29	4	1930	1476.9-1486.5	265.1-274.7	9.6	9.29	97
30	4	2000	1486.5-1496.1	274.7-184.3	9.6	8.52	89
31	4	2035	1496.1-1505.7	284.3-293.9	9.6	8.90	93
32	4	2135	1505.7-1515.3	293.9-303.5	9.6	0.00	0
33	4	2235	1515.3-1524.9	303.5-313.1	9.6	0.30	3
34	4	2335	1524.9-1534.5	313.1-322.7	9.6	7.43	77
35	5	0010	1534.5-1544.1	322.7-332.3	9.6	7.88	82
36	5	0120	1544.1-1553.7	332.3-341.9	9.6	6.87	71
37	5	0225	1553.7-1563.3	341.9-351.5	9.6	1.93	20
38	5	0310	1563.3-1572.9	351.5-361.1	9.6	3.64	38
39	4	0400	1572.9-1582.5	361.1-370.7	9.6	3.16	33
40	4	0430	1582.5-1592.1	370.7-380.3	9.6	5.74	60
41	4	0500	1592.1-1601.7	380.3-389.9	9.6	6.55	68
42	5	0540	1601.7-1611.3	389.9-399.5	9.6	5.73	60
43	5	0640	1611.3-1620.9	399.5-409.1	9.6	2.04	43
44	5	0730	1620.9-1630.5	409.1-418.7	9.6	1.99	21
45	5	0820	1630.5-1640.1	418.7-428.3	9.6	2.49	26
46	5	0915	1640.1-1649.7	428.3-437.9	9.6	2.95	31
47	5	1010	1649.7-1659.3	437.9-447.5	9.6	1.62	17
48	5	1040	1659.3-1668.9	447.5-457.1	9.6	3.19	33
49	5	1140	1168.9-1678.5	457.1-466.7	9.6	5.35	56
50	5	1250	1678.5-1688.1	466.7-476.3	9.6	2.34	24
51	5	1340	1688.1-1697.7	476.3-485.9	9.6	1.72	18
52	5	1410	1697.7-1707.3	485.9-495.5	9.6	2.79	29
53	5	1515	1707.3-1716.9	495.5-505.1	9.6	0.58	6
					505.1	299.72	59.3
Hole 594A							
	Wash		1211.8-1253.1	0.0-41.3			
1	6	0550	1253.1-1262.7	41.3-50.9	9.6	9.80	100+
2	6	0625	1262.7-1272.3	50.9-60.5	9.6	9.02	93.5
3	6	0700	1272.3-1281.9	60.5-70.1	9.6	8.16	85.0
4	6	0750	1281.9-1291.5	70.1-79.7	9.6	9.21	95.9
5	6	0835	1291.5-1301.1	79.7-89.3	9.6	9.35	97.4
6	6	0915	1301.1-1310.7	89.3-98.9	9.6	8.84	92.0
7	6	0940	1310.7-1320.3	98.9-108.5	9.6	8.62	89.8
8	6	1045	1320.3-1329.9	108.5-118.1	9.6	8.43	87.8
9	6	1140	1329.9-1339.5	118.1-127.7	9.6	9.43	96.0
	Wash						
10	6	1245	1361.7-1371.3	149.9-159.5	9.6	9.52	99.0
	Wash						
11	6	1355	1409.7-1419.3	197.9-207.5	9.6	7.57	79.0
H1	Wash						
12	6	1845	1707.3-1716.9	495.5-505.1	9.6	2.12	22.0
13	6	1930	1716.9-1726.5	505.1-514.7	9.6	8.17	85.0
14	6	2035	1726.5-1736.1	514.7-524.3	9.6	7.18	75.0
15	6	2120	1736.1-1745.7	524.3-533.9	9.6	4.55	47.0
16	6	2220	1745.7-1755.3	533.9-543.5	9.6	8.65	90.1
17	6	2305	1755.3-1764.9	543.5-553.1	9.6	6.35	66.1
18	7	0005	1764.9-1774.5	553.1-562.7	9.6	4.98	51.8
19	7	0100	1774.5-1784.1	562.7-572.3	9.6	2.36	24.6
20	7	0200	1784.1-1793.7	572.3-581.9	9.6	3.87	40.3
21	7	0300	1793.7-1803.3	581.9-591.5	9.6	2.60	27.0
22	7	0400	1803.3-1812.9	591.5-601.1	9.6	1.09	11.3
23	7	0515	1812.9-1822.5	601.1-610.7	9.6	2.86	29.7
24	7	0615	1822.5-1832.1	610.7-620.3	9.6	2.92	30.4
25	7	0720	1832.1-1841.7	620.3-629.9	9.6	3.17	33.0
26	7	0835	1841.7-1851.3	619.9-639.5	9.6	2.73	28.4
					249.60	161.55	64.7
Hole 594B							
1	7	1110	1212.2-1216.7	0.0-4.5	4.5	4.50	100
2	7	1142	1216.7-1226.3	4.5-14.1	9.6	8.36	87
3	7	1230	1226.3-1235.9	14.1-23.7	9.6	3.78	39
4	7	1300	1235.9-1245.5	23.7-33.3	9.6	8.61	90
5	7	1335	1245.5-1255.1	33.3-42.9	9.6	8.93	88
					42.90	34.18	79.6

because weather conditions were still questionable. The upper five piston cores taken in the first hole were very complete, so that missing the interval the second time was a reasonable expediency. Nine 9.5-m VLHPC cores were then taken, with excellent recovery on all.

The bit was next washed to 149.9 m BSF and the XCB deployed to take a core which was missed in Hole 594. This procedure was repeated to recover the 9.6 m interval starting at 197.5 m BSF. The XCB was then used as a wash barrel and the bit was washed to 495.5 m BSF to commence continuous XCB coring to the Eocene objective.

XCB coring proceeded to 639.5 m BSF through carbonate chalk and interbedded turbidites. Cores were interesting but only the turbidite sequences were relatively undisturbed. The firm sediment tended to jam in the cutting shoe, keeping recovery totals low. The hole was terminated in Miocene sediments, when fossil preservation had decreased too far to be of further analytical value.

Hole 594B

The bit was pulled to the mudline and the 9.5-m VLHPC was again rigged. Time and weather conditions allowed the top five piston cores previously missed to be taken before leaving the site. The hole was spudded at 1052 hr., 7 January, with a mudline core which contained as a bonus one arm of an Ophiuoroid (brittle star). Water depth was established to be 1212.2 m. The five cores were taken with dispatch and the pipe was pulled for the final time on this voyage.

LITHOSTRATIGRAPHY

Site 594 consists of three holes (Fig. 3) cored to a maximum sub-bottom depth of 639.5 m. Hole 594 was continuously cored with the HPC from 0 to 130.7 m sub-bottom and continued to a total depth of 505.1 m with the XCB. HPC recovery was about 73%, and XCB recovery was 79% from 130.7 to 293.9 m sub-bottom, but only 36% from 293.9 to 505.1 m. Hole 594A was washed down to 41.3 m, continuously cored with the HPC from 41.3–127.7 m, and then washed with the XCB from 127.7–149.9 m and 159.5–197.9 m. Cores were taken from 149.9–159.5 and 197.9–207.5 m, thereby giving close to complete core recovery from 0–207.5 m sub-bottom depth (Holocene to latest Miocene). Below 207.5 m Hole 594A was washed to 495.5 m and thereafter continuously cored with the XCB to a total sub-bottom depth of 639.5 m (late early Miocene), but recovery over this last interval was generally low (44%). Hole 594B was continuously cored with the HPC from 0 to 42.9 m sub-bottom. These cores were not opened.

The recovered sequence at Site 594 is assigned to two lithostratigraphic units (I and II), the second of which is further subdivided into Subunits IIA and IIB (Fig. 3). Divisions are based primarily on differences in composition as reflected in color changes, as well as degree of lithification (Table 2).

Unit I consists of an alternating sequence of pelagic and hemipelagic lithofacies generally defined by bluish gray and greenish gray sediment, respectively. Pelagic-hemipelagic cycles range in thickness from 0.5 to 10 m.

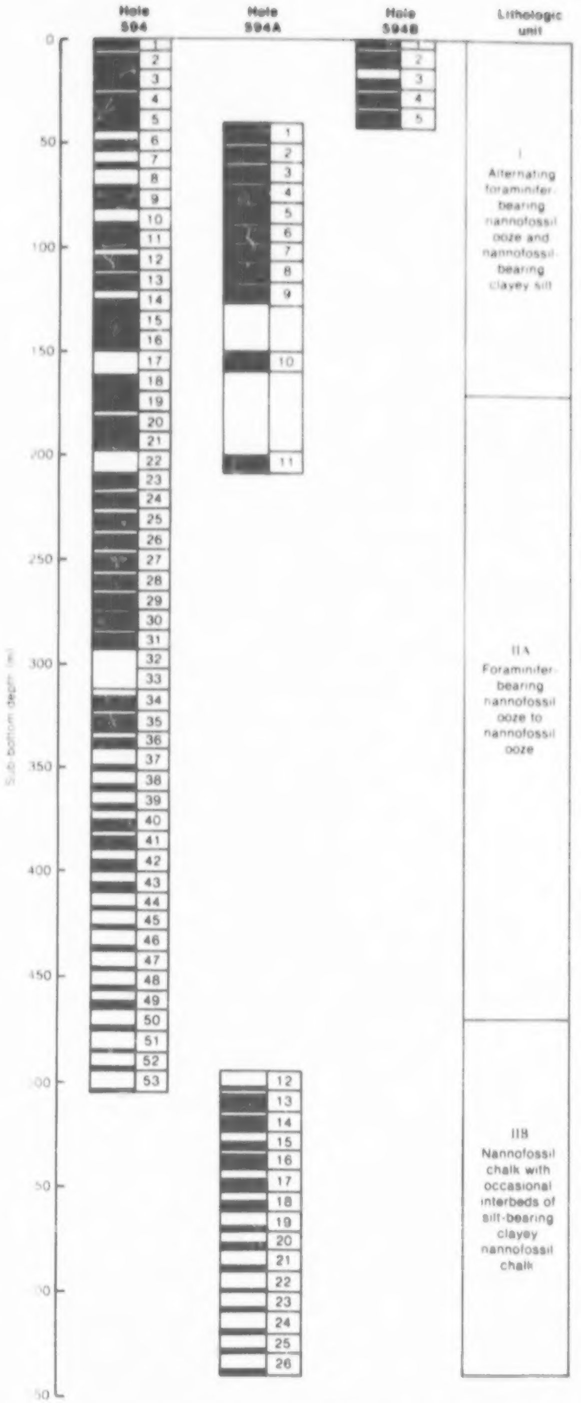

Figure 3. Summary of core recovery and lithostratigraphic units at Site 594 (recovery in black).

Table 2. Lithostratigraphy at Site 594.

Lithologic unit	Cores	Sub-bottom depth (m)	General lithology	Age
I	1-18 1A-10A 1B-5B	0.0-169.1 41.3-159.5 0.0-42.9	Alternating bluish gray foraminifer-bearing nannofossil ooze and greenish gray nannofossil-bearing clayey silt	late Quaternary to earliest Pliocene
IIA	19-49 11A	169.1-466.7 197.9-207.5	Light to very light gray foraminifer-bearing nannofossil ooze to nannofossil ooze	Earliest Pliocene to early middle Miocene
IIB	50-53 12A-26A	466.7-505.1 495.5-639.5	Very light gray nannofossil chalk with occasional interbeds of olive gray silt-bearing clayey nannofossil chalk	Early middle Miocene to late early Miocene

Note: A, B indicate cores from Holes 594A, B, respectively.

Contacts between lithofacies are completely gradational, subtle color variations between the end-member bluish gray and greenish gray colors. Bioturbation is moderately intensive throughout the unit and color mottling by burrowing is especially well defined across and within the color gradation between lithofacies. Sediments are soft but stiff throughout.

The pelagic lithofacies consists mainly of foraminifer-bearing nannofossil ooze, foraminifer- and clay-bearing nannofossil ooze, or foraminifer-bearing clayey nannofossil ooze. It is light bluish gray (5B 7/1) to medium bluish gray (5B 5/1), less commonly light gray (N7). The intensity of blueness appears to increase with increased clay content. Sediments are massive, with common mottles and hues in pale olive (10Y 6/2) tones. Streaks and blebs of dark gray (N4) pyritized sediment are scattered throughout. The lithofacies is dominated by calcareous nannofossils, with rare to common foraminifers and clay minerals, and trace and rare amounts of quartz, feldspars, mica, and biogenic siliceous components that include sponge spicules, diatoms, and radiolarian fragments (Fig. 4). Other minor detrital grains include volcanic glass, ferromagnesium minerals, pyrite, and glauconite.

The hemipelagic lithofacies consists of a variety of sediment intergrades between a clay- and silt-bearing nannofossil ooze and a nannofossil-bearing clayey silt; the lithofacies is commonly diatom- and sponge-spicule-bearing, rarely foraminifer-bearing. It is greenish gray (5G 6/1) to dark greenish gray (5G 4/1), with common pale olive (10Y 6/2) to light gray (N7) burrow mottles and scattered dark gray (N4) pyritized spots. Dominant components are varying quantities of calcareous nannofossils, clay minerals, and silt-sized grains of quartz, feldspar, and mica (Fig. 4); occasionally the content of nannofossils drops to rare. Foraminifers and siliceous biogenic components are rare to common. Trace to rare quantities of volcanic glass, heavy minerals, and pyrite occur, and minor amounts of glauconite persist. Compared to the pelagic lithofacies, the sediment is relatively enriched in both terrigenous silt and clay and in biogenic siliceous components, notably sponge spicules and diatoms, and relatively depleted in both foraminifers and nannofossils (Fig. 4).

Distinctive, thin, light olive gray (5Y 6/1) vitric ash beds were observed in Unit I at 36.5, 103.8, and 121.0 m sub-bottom depth in Hole 594 and at 112.0 and 157.5 m sub-bottom depth in Hole 594A. A New Zealand source is most likely.

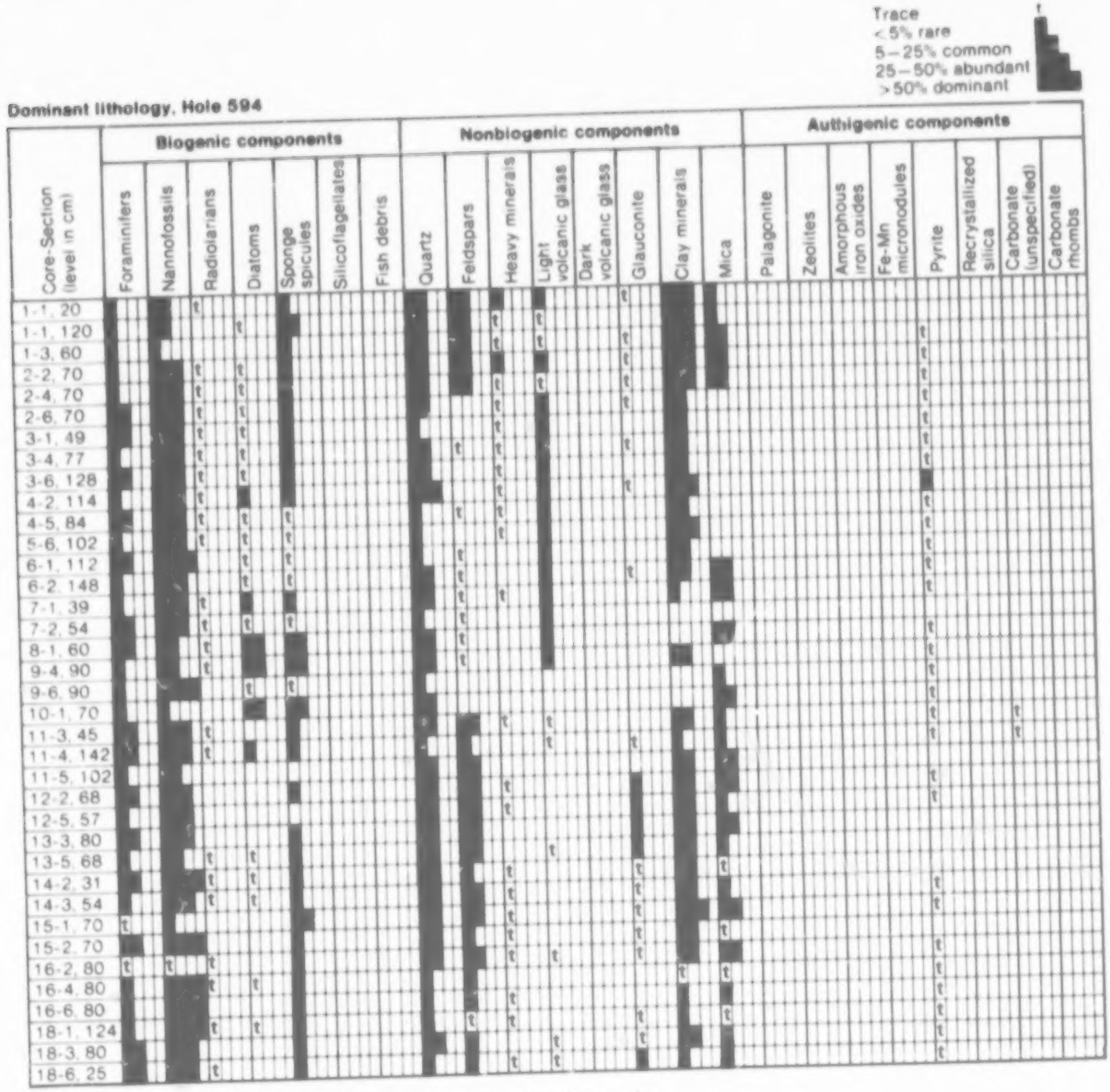

Figure 4. Smear slide summaries, Site 594. Asterisk indicates insoluble residue.

The contact between Units I and II is gradational over several meters but is recognized by the change from interbedded pelagic and hemipelagic facies of Unit I to a pelagic facies of Unit II. The major lithofacies of Unit II is a foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk). The ooze/chalk transition occurs at about 470 m sub-bottom depth and forms the basis for separating the two subunits of Unit II. The nannofossil chalk below 533.8 m sub-bottom depth includes conspicuous olive gray interbeds of silt-bearing clayey nannofossil chalk.

Subunit IIA is a very light to light gray (N8 to N7) foraminifer-bearing nannofossil ooze that grades down into a nannofossil ooze by 245 m sub-bottom depth. Occasional yellowish gray (5Y 8/1) hues and burrow mottles, rare pale purple (5P 6/2) pyritized blebs and streaks, and scattered dark gray (N4) pyrite specks are superimposed on the predominantly massive sediment. Calca eous nannofossils dominate the components and fora minifers are generally common above 245 m sub-botto depth but they form only trace to rare amounts belo this level. Biogenic siliceous remains persistently occu throughout in trace to rare abundances and several o the slightly darker gray (N6 to N7), thin interbeds a sufficiently enriched in these components to be diaton and sponge spicule-bearing nannofossil oozes. Terrig nous material, including quartz, feldspar, mica, and cla minerals, is present in only rare to trace abundances an generally decreases in content with depth. Small concr tionary nodules and blebs of pyrite, chert, and possibl celestite occur in rare abundances and are sometimes as sociated with burrow structures. Bioturbation is mod erate to very intensive throughout, but is difficult to evaluate in several sections composed of almost totall

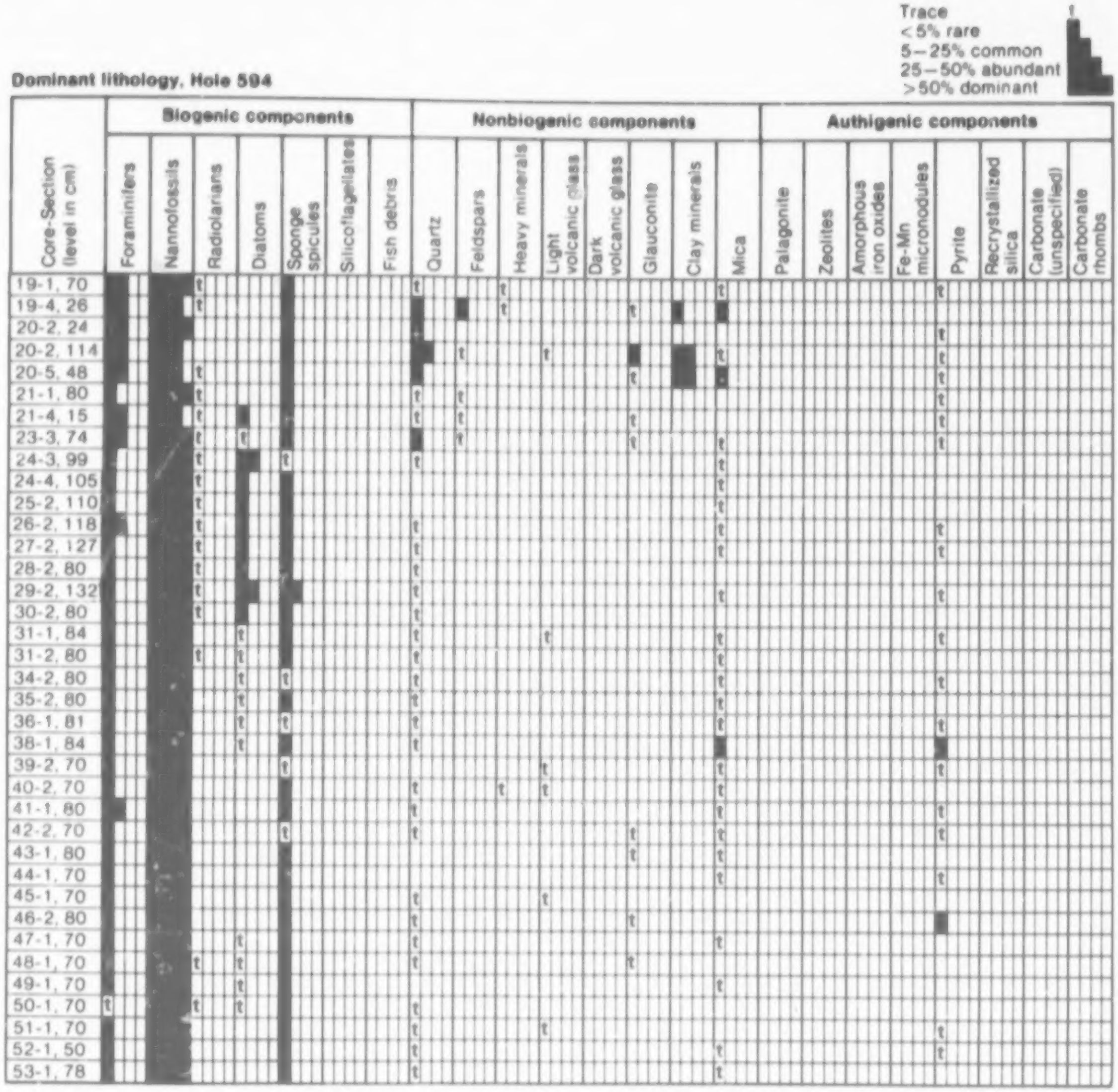

Figure 4. (Continued).

tureless nannofossil ooze, from about 300 m sub- tom depth down to the ooze/chalk transition mark- the boundary with Subunit IIB at about 466 m sub- tom.

Subunit IIB comprises very light gray (N8) nannofos- chalk which includes interbeds of olive gray (5Y 4/1), -bearing, clayey nannofossil chalk below 533.8 m sub- tom. The nannofossil chalk is rarely foraminifer-bear- , and exhibits progressive recrystallization of its bio- ic carbonate grains with depth, especially below about m sub-bottom. Flaser-like bedding is first observed bout the same depth. The flasers become more pro- unced and begin to resemble stylolites at about 600 Distinctive pale to dark green (5G 7/2 to 10G 4/1) inae, often in composite sets, occur commonly in subunit. The laminae may represent altered volcanic glass, although some clearly cross-cut burrow structures, and their exact origin is uncertain. Bioturbate structures are well preserved, with many examples of Zoophycos, Chondrites, and Planolites traces depicted in yellowish gray (5Y 8/1) to light gray (N7) tones. They are dominated by calcareous nannofossils with common micas and clay minerals, rare foraminifers, and occasional quartz and feldspar grains. Biogenic siliceous components are also more conspicuous than in the intervening light gray nannofossil chalks, and some olive gray beds are sponge-spicule- and silt-bearing clayey nannofossil chalks. Textures range from medium to very fine silt at the base of beds to clay-dominated at the top. Habitat stratification is pronounced in the infaunal burrow types in the thicker beds in the upper portion of units, with Planolites between 0 and about 5 cm, Chondrites below to depths of

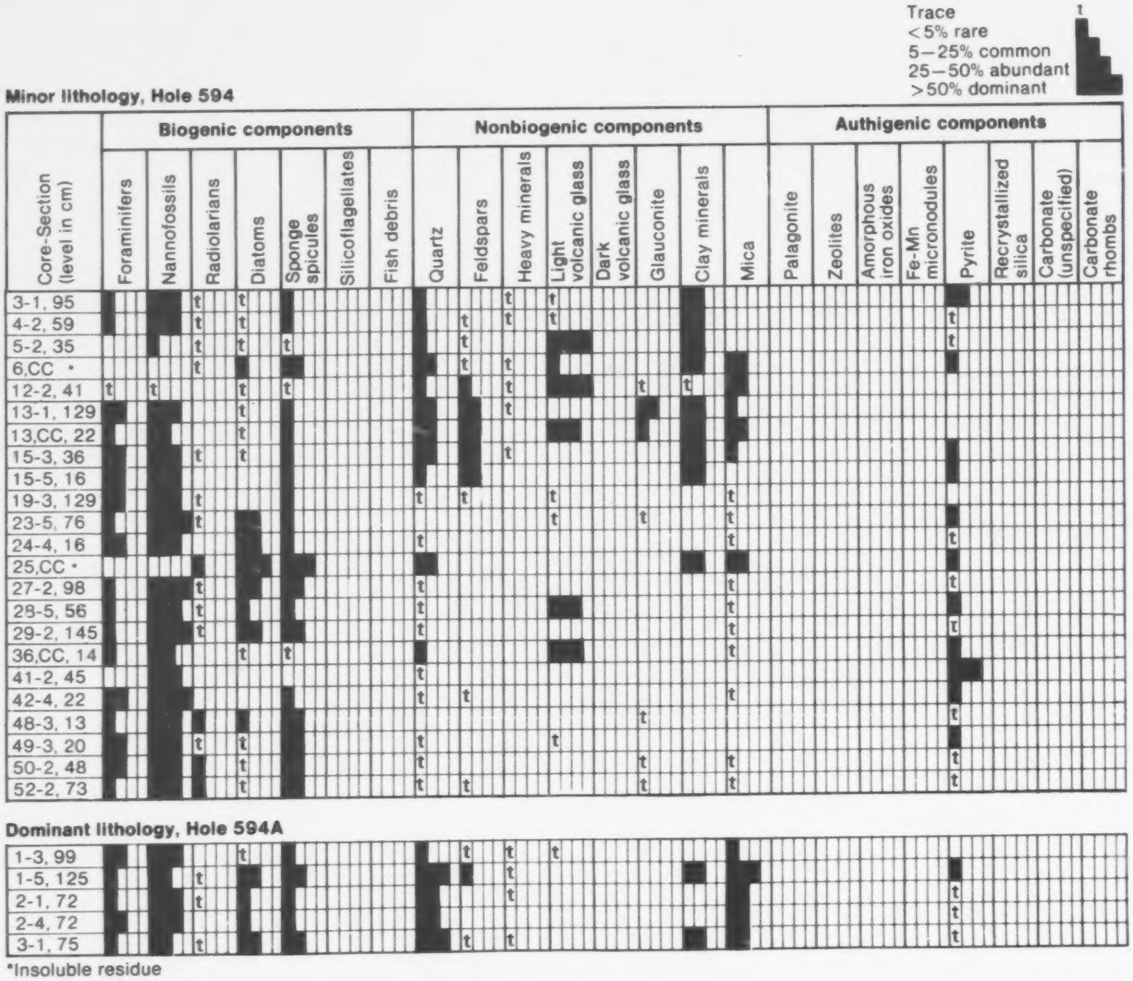

Figure 4. (Continued).

10 cm, and finally Zoophycos, to depths of 15 to 20 cm. The sedimentary structures indicate these sediments are turbidite deposits.

Discussion

Site 594 is a 640-m-thick sequence of pelagic nannofossil oozes (chalks) and hemipelagic silts and clays of late early Miocene through late Quaternary age. The upward stratigraphic succession (Table 2) from alternating pure and impure chalks (Subunit IIB) to alternating pelagic carbonate oozes and hemipelagic muds (Unit I) can be broadly interpreted in terms of changing tectonic tempo on the New Zealand landmass as well as paleoclimatic changes.

The nannofossil chalks in Subunit IIB are the sedimentary record of normal oceanic pelagic conditions in the late early to early middle Miocene. The interbedded clay- and silt-rich chalk-turbidites suggest that tectonism and erosion in the New Zealand region was sufficiently active to supply large volumes of fine terrigenous sediment to the area of Site 594. Accumulation rates for late early Miocene sediments at Site 594 probably exceeded 50 m/m.y. Significantly, major strike-slip motion was occurring along the Alpine Fault sector of the Indian/Pacific plate boundary at this time, and thick sequences of early Miocene flysch are characteristic of coeval sedimentary sequences in New Zealand (Carter and Norris, 1976; Nelson and Hume, 1978). The thin, pale green layers of probably altered ash in the chalk may have originated from explosive arc volcanism associated with the early Miocene inception of the Indian/Pacific plate boundary in its present form through New Zealand (Ballance, 1976). There is paleontological evidence for considerable reworking of microfaunas in the purer chalks of Subunit IIB.

The relatively homogeneous, pure nannofossil oozes of Subunit IIA record a period of less intensive uplift in the New Zealand region with virtually no terrigenous sediment influx at Site 594 for the remainder of most of the Miocene. Thin intervals within the subunit that are relatively enriched in diatoms, sponge spicules, and/or foraminifers may correspond to periods of accelerated

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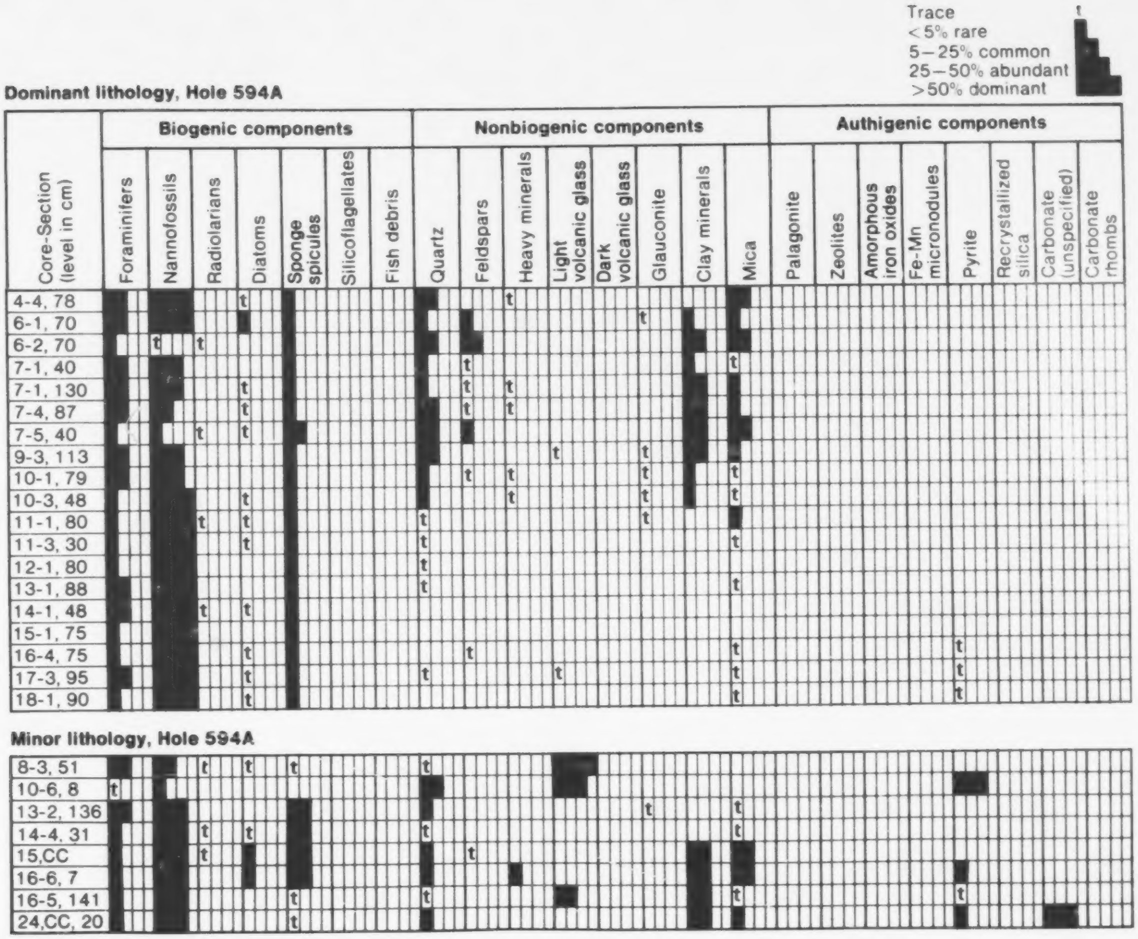


Figure 4. (Continued).

seafloor winnowing. These intervals increase in abundance within the upper levels of Subunit IIA at the same time as fine terrigenous material begins to reappear in more than trace amounts. Thin interbeds of clay-, silt-, and foraminifer-bearing nannofossil ooze occur below the transition into Unit I and may herald a fundamental change in both New Zealand tectonics and the global climatic regime about 5 to 6 m.y. ago.

The sudden increase in abundance of fine terrigenous sediment at the bottom of Unit I and its continued abundance throughout the unit are interpreted as indicating rapid uplift of the New Zealand Alps along the Alpine Fault Zone since about 6 m.y. ago. The inception of this orogenic phase, the Kaikoura Orogeny in New Zealand, coincides with the transition from Units II to I sediments. Unit I is characterized by a large number of oscillations between greenish gray hemipelagic and bluish gray calcareous biogenic facies. The former is enriched in terrigenous silt, clay, and fine sand, as well as biosiliceous components, whereas the latter is mainly a foraminifer-bearing nannofossil ooze. At least 25 major hemipelagic sediment episodes have occurred during the last 5 m.y. and numerous intermediate or lesser events are also recorded by color alternations. These sedimentary cycles are largely interpreted as resulting from sea level oscillations, the hemipelagic facies being deposited during glacial low stands of sea level.

PHYSICAL PROPERTIES

The initial 200 m consist of a hemipelagic sequence with gradually increasing bulk density, shear strength, and sonic velocity. Beyond this depth, alternating sequences of pelagic and hemipelagic sediments produce erratic physical properties records. Porosity results depict no consistent pattern until the 500-m level in Hole 594A, where this properly decreases sharply. Sonic velocity values increase beyond this depth and show large variations between measurements obtained through the light-colored chalk and those determined from the darker, irregular layers of turbidite deposits. Although the shear strength results are quite variable, it was possible to continue taking measurements down to a depth of 470 m before the sediment became too lithified and exceeded the capability of the miniature vane shear apparatus.

Physical properties data are shown in Figure 5.

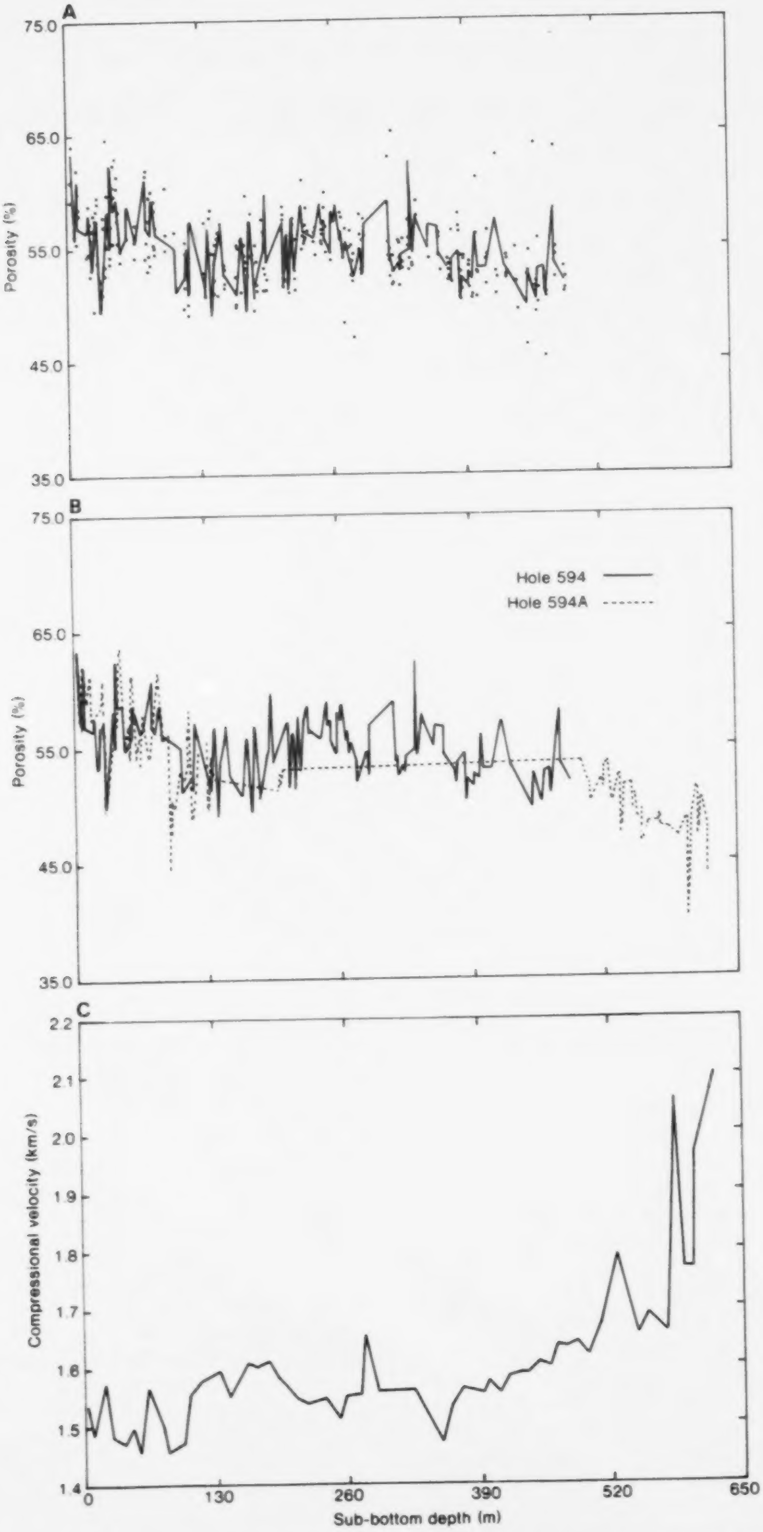


Figure 5. Physical properties results for Site 594. A. GRAPE porosity versus sub-bottom depth. B. GRAPE porosity versus sub-bottom depth (Holes 594 and 594A). C. Compressional velocity versus sub-bottom depth. D. Shear strength versus sub-bottom depth. E. Porosity versus compressional velocity. F. Porosity versus shear strength. G. Acoustic impedance versus sub-bottom depth.

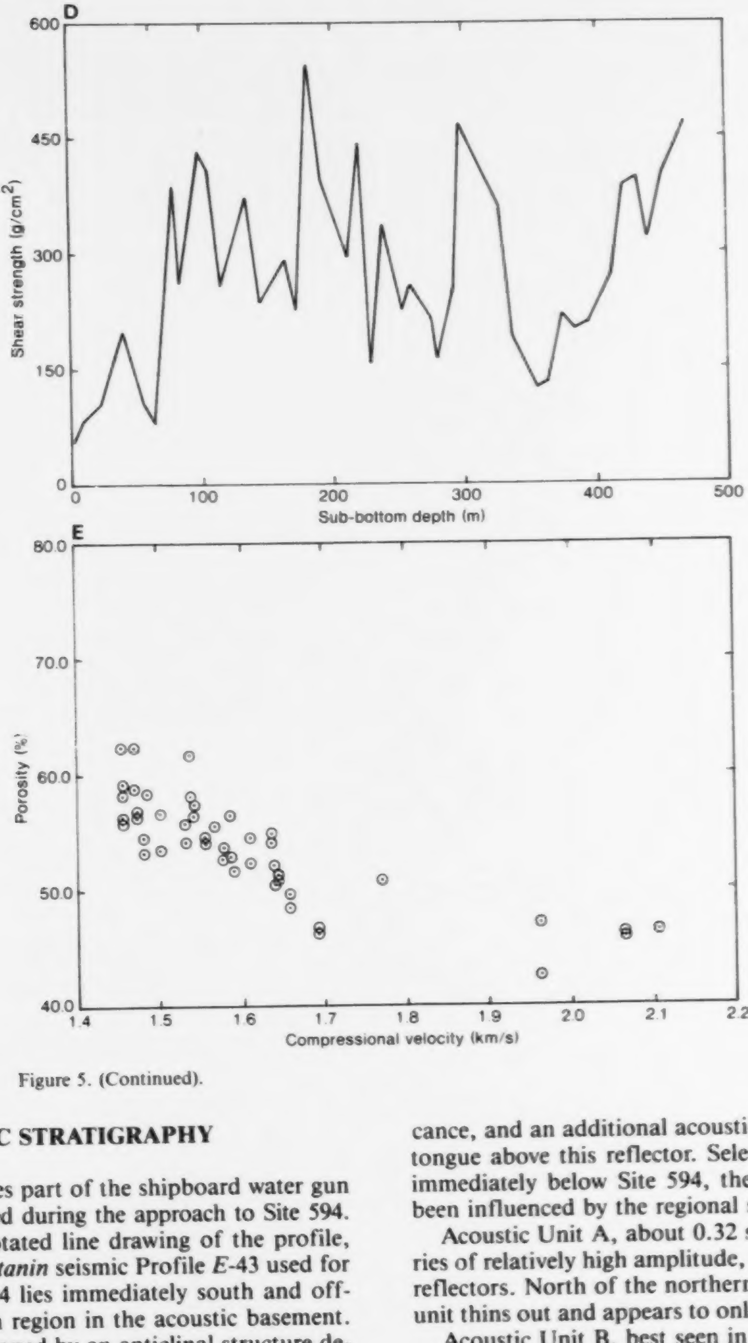


Figure 5. (Continued).

SEISMIC STRATIGRAPHY

Figure 6A illustrates part of the shipboard water gun seismic profile collected during the approach to Site 594. Figure 6B is an annotated line drawing of the profile, and Figure 7 is the *Eltanin* seismic Profile *E*-43 used for site selection. Site 594 lies immediately south and off-structure from a high region in the acoustic basement. This high region is draped by an anticlinal structure developed within the sediment blanket.

Unfortunately, because of the proximity of the high, acoustic horizons are somewhat confused immediately below the drill site. Only two acoustic Units, A and C, can be tentatively recognized there, overlying acoustic basement which is at about 1 s sub-bottom. However, a gently dipping regional reflector, Reflector X (Fig. 6B), can be seen to separate two zones of regional significance, and an additional acoustic unit, Unit B, forms a tongue above this reflector. Selection of acoustic units immediately below Site 594, therefore, has necessarily been influenced by the regional seismic profile.

Acoustic Unit A, about 0.32 s thick, comprises a series of relatively high amplitude, closely spaced, parallel reflectors. North of the northern limit of Figure 6, this unit thins out and appears to onlap Reflector A (Fig. 7).

Acoustic Unit B, best seen in Figure 6B, wedges out to the north near the northern limit of the figure. This unit is more transparent than A, but contains diffuse reflectors.

Acoustic Unit C at Site 594 encompasses a zone acoustically more transparent than Unit A. Like Unit B, it contains a series of coherent reflectors. However, the basal portion of C, immediately overlying basement, appears more transparent, with less coherent reflectors.

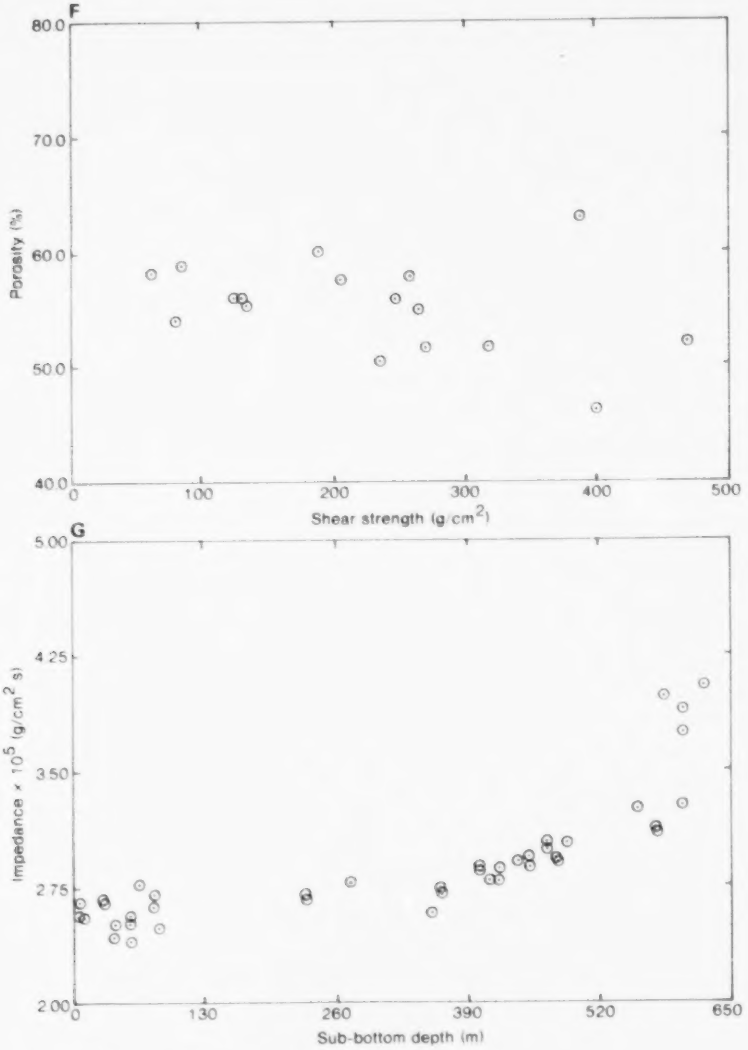


Figure 5. (Continued).

Site 594 was drilled to a total depth of 639.5 m. The sediments have been assigned to two lithologic units, Units I and II. Unit II is subdivided into Subunits IIA and IIB.

Unit I comprises an alternating sequence of pelagic and hemipelagic ooze of Pliocene to Quaternary age. Unit IIA is a foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk), and IIB is a nannofossil chalk with graded olive gray interbeds of silt-bearing clayey nannofossil chalk. The ooze/chalk boundary occurs at a sub-bottom depth of about 466 m in Hole 594.

An interval velocity of 1600 m/s is assumed for this site, based on averaged shipboard velocimeter measurements. Comparison of this lithologic sequence with the seismic profile is difficult in the immediate vicinity of Site 594 because of the problems mentioned earlier. However, if comparisons are made with the profile a few miles north of the site, it is apparent that acoustically stratified Unit A incorporates part of lithostratigraphic Unit I and the upper portion of IIA. The wedge-shaped acoustic Unit B presumably corresponds with part of the pelagic ooze lithologic Unit IIA. Reflector X, by this reasoning, may correspond with the top of lithostratigraphic Unit IIB, marking the upper level of the silty turbidite and chalk sequence cored toward the bottom of the hole.

BIOSTRATIGRAPHY

Site 594 is located on the southwestern side of the Chatham Rise in 1204 m of water; the Subtropical Convergence lies just to the north of the site. The nannofossil and planktonic foraminiferal zones are shown in Figures 8 and 9.

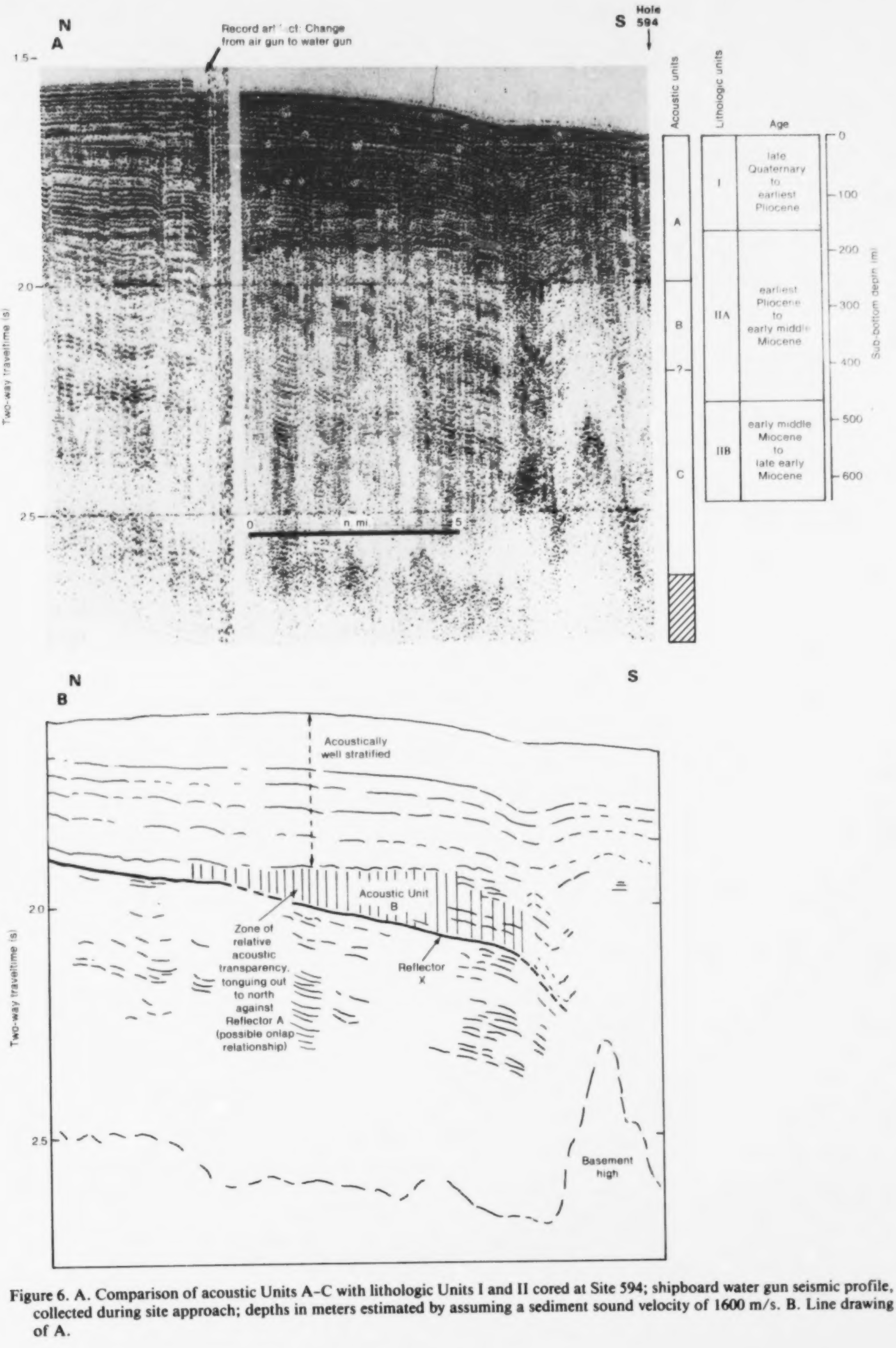


Figure 6. A. Comparison of acoustic Units A-C with lithologic Units I and II cored at Site 594; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1600 m/s. B. Line drawing of A.

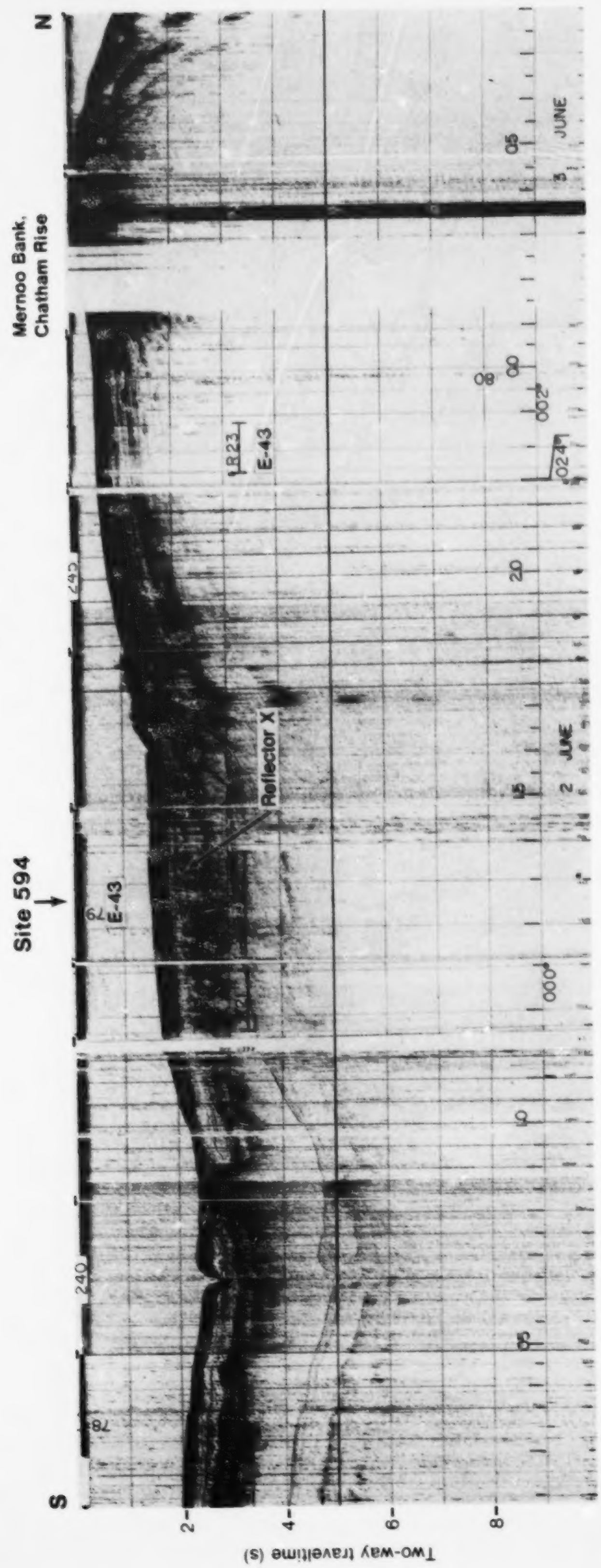


Figure 7. *Eltanin* E-43 seismic profile used for site selection.

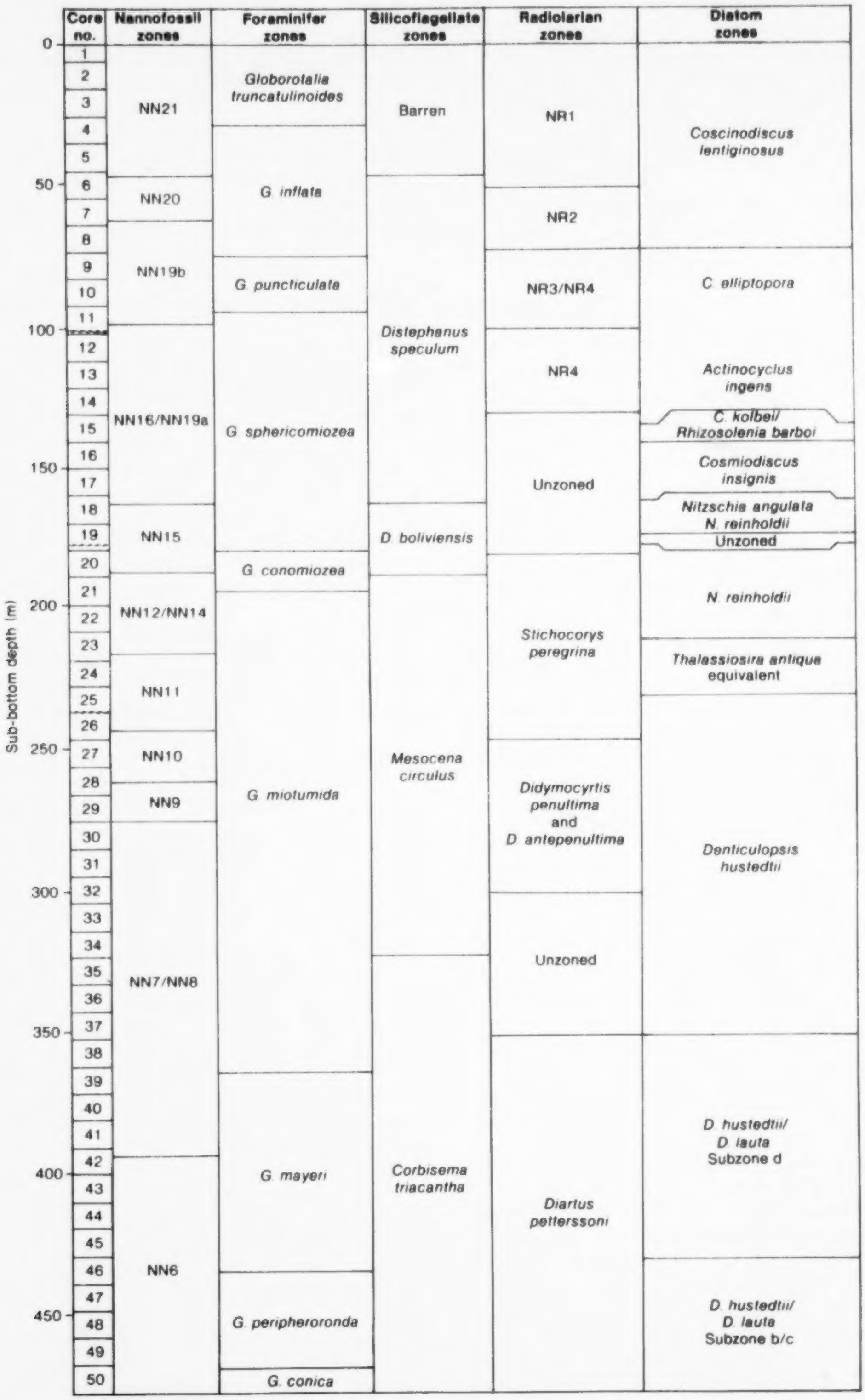


Figure 8. Biostratigraphy of Hole 594.

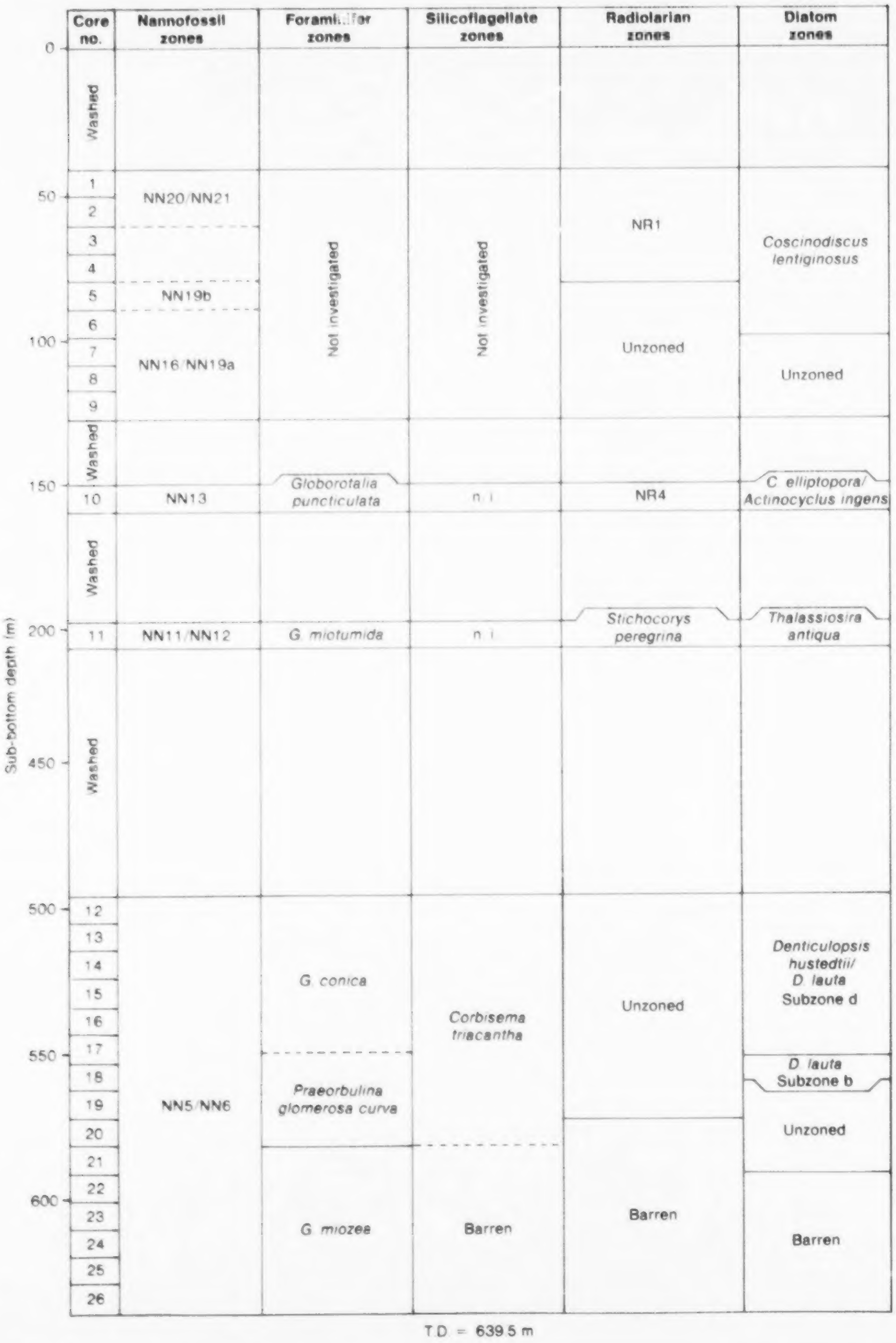

Core no.
Nannofossil zones
Foraminifer zones
Silicoflagellate zones
Radiolarian zones
Diatom zones
Sub-bottom depth (m)
0
50
100
150
200
450
500
550
600
Washed
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
NN20/NN21
NN19b
NN16/NN19a
NN13
NN11/NN12
NN5/NN6
Not investigated
Globorotalia puncticulata
G. miotumida
G. conica
Praeorbulina glomerosa curva
G. miozea
n. i.
Corbisema triacantha
Barren
NR1
Unzoned
NR4
Stichocorys peregrina
Coscinodiscus lentiginosus
C. elliptopora/Actinocyclus ingens
Thalassiosira antiqua
Denticulopsis hustedtii/D. lauta Subzone d
D. lauta Subzone b
T.D. = 639.5 m

Figure 9. Biostratigraphy of Hole 594A.

The planktonic foraminifers exhibit low species diversity and at certain levels also low numbers of specimens. Preservation is generally good from Pleistocene to lower Miocene but deteriorates in the middle and lower Miocene. Calcareous nannoplankton exhibit low diversity throughout; preservation is moderate to good in the Pliocene–Pleistocene and moderate to poor in the Miocene. In the few well-preserved samples of the section, benthic foraminifers are abundant and generally well preserved; however, breakage is common throughout the section. Both benthic and planktonic foraminifers are recrystallized in the lower Miocene.

Radiolarians, diatoms, and silicoflagellates occur throughout the cored section; sponge spicules are very common in the coarse fractions.

Radiolarians are moderately well preserved, and because equatorial and high-latitude faunas are mixed the zonation uses zones from both regions. There is a significant change in Core 21 and above, where antarctic and subantarctic species become dominant.

Diatoms are best preserved in the middle to late Miocene and are present throughout in the sequence younger than the early Miocene. The diatom assemblages suggest that since the Miocene the site has been located below the subantarctic water mass. Diatom datums have been correlated with magnetostratigraphy established elsewhere.

Many planktonic foraminiferal markers are present in the Pleistocene to late middle Miocene, but in the early middle and late early Miocene there were some difficulties in recognizing established zones. The problems are due to (1) the sporadic occurrence of index species such as *Orbulina suturalis* and the lack of others, including *Praeorbulina glomerosa* and *Globigerinoides trilobus;* and (2) massive reworking of early Miocene faunas in Cores 594-50 to 594-53 and in 594A-12 to 594A-20. Another problem involved the late appearance of some zonal markers including *Globorotalia truncatulinoides* and *G. inflata* because of the position of the site in the subantarctic water mass.

Most zonal indicators of the calcareous nannoplankton are absent or extremely rare and the zones were partly determined by using auxiliary species.

Silicoflagellates were examined in all core-catcher samples; it was possible to place them within the zonation established during Leg 38 by Martini and Müller (1976).

Planktonic foraminiferal studies indicate alternations of cold and warm periods in the Pliocene–Pleistocene. These cold and warm faunas could be explained by assuming north–south fluctuations of the Subtropical Convergence over Site 594; currently the Convergence is situated north of the site.

Benthic faunas are depleted but indicate the presence of warmer bottom waters in the late early Miocene, and an episode of cool and corrosive waters in the early late Miocene.

Four unconformities were detected, mainly by diatom evidence, in the upper Miocene through Quaternary. In ascending order, they were located in (1) Core 24, (2) Core 20, (3) Core 16, and (4) Core 11.

Planktonic Foraminifers

Zones

The following zones were identified at Site 594; the zonal boundary markers are shown below:

Globorotalia truncatulinoides Zone
  I.A. *G. truncatulinoides*
Globorotalia inflata Zone
  I.A. *G. inflata*
Globorotalia puncticulata Zone
  L.A. *G. sphericomiozea*
Globorotalia sphericomiozea Zone
  L.A. *G. conomiozea*
Globorotalia conomiozea Zone
  I.A. *G. conomiozea*
Globorotalia miotumida Zone
  L.A. *G. mayeri*
Globorotalia mayeri Zone
  L.A. *G. peripheroronda*
Globorotalia peripheroronda Zone
  L.A. *G. conica*
Globorotalia conica Zone
  I.A. *G. conica*
Praeorbulina glomerosa curva Zone
  I.A. *P. glomerosa curva*
Globorotalia miozea Zone

The position of the site in subantarctic waters appears to have affected the faunas from the early Miocene to the Quaternary. Consequently, the zonal scheme is different from that at temperate-water Site 593; also, the boundaries of some zones at Site 594 could be higher and/or lower than at Site 593. For example, the initial appearance of *G. truncatulinoides* at Site 594 is within the late Pleistocene, as in other subantarctic areas.

Specimens of the evolutionary lineage of *Orbulina* are very rare at this site and it was not possible to identify properly the *O. suturalis* Zone. Similarly, because of the lack of *Globigerinoides* it was not possible to identify the *G. trilobus* Zone. Consequently, another set of zones, in ascending order, were established for Site 594: *Globorotalia miozea, Praeorbulina glomerosa curva, G. conica*, and *G. peripheroronda.*

Paleobiogeography

The planktonic foraminiferal faunas were reasonably well preserved from the Pleistocene through to the middle Miocene, where they deteriorated; they improved again in the lower Miocene. The species diversity is lower throughout, with low numbers of species; at certain horizons there is marked dissolution, as for example in the early Pliocene Sample 594-16,CC. In Samples 594-42,CC and 594-43,CC there was a low number of species and specimens which coincided with a massive influx of radiolarians.

The faunas of the Pleistocene through Pliocene appear to show alternating cold and warm episodes; the cold-water intervals are indicated by lower species diversity, whereas warmer waters supported such additional species as *Orbulina universa, Globorotalia crassaformis*, and *Globigerinatella aequilateralis*. One possible explanation is the latitudinal fluctuations of the Subtropical Convergence, which are probably associated with glacial-interglacial oscillations.

Benthic Foraminifers

Benthic foraminifers were examined from all core catchers from Hole 594 and in Samples 594A-12,CC to 594-26,CC. Throughout the entire section, only five to six samples are considered to contain undissolved benthic faunas. In the majority of the samples benthics are dissolved, broken, or have disappeared. In general, the larger the percentage of radiolarians or mica in a sample, the fewer the benthics and the worse their preservation.

In general the benthic faunas resemble those of Sites 592 and 593; cibicidids, uvigerinids, and *Oridorsalis* are common in most samples. *Ehrenbergina, Osangularia, Bolivina*, and, below the Pliocene, *Bulimina* are rarely found. In the best-preserved samples, specimens are very large, with the exception of a few species such as *Pleurostomella alternans*, which becomes both smaller and rarer at these southerly sites. Unlike at other sites, faunas at Site 594 often demonstrate unusually high dominance of one or two species at specific times. These include a pulse of *Nuttalides umbonifera* in the upper Miocene, of *Cibicides wuellerstorfi* in the lower Miocene, and of shallow-water angulogerinids and bolivinitids in the Quaternary and lower Pliocene.

Despite the poor preservation of the benthics through much of the Miocene, two important changes take place. The first, in the lower to middle Miocene (594A-16 to 594A-18,CC), involves a marked increase in the numbers of *C. wuellerstorfi*, accompanied by a loss of uvigerinids and the first and only appearance of *Osangularia bengalensis*, a species rare in the southern sites of this traverse. These faunal changes may reflect a late early Miocene warming and a decrease in nutrients at the bottom, or the positioning of the site near the Subtropical Convergence, which carries warmer, surface waters to greater depths.

In the upper Miocene (594-36 to 594-38,CC, lower *Globorotalia miotumida* Zone) there is a large increase in the abundance of *N. umbonifera* accompanied by important changes in the radiolarian assemblages. *N. umbonifera* is generally associated with Antarctic Bottom Water and corrosive bottom water. The benthic faunas suggest that there was an intense cooling pulse and/or an increase in the corrosiveness of the bottom-water environment at this site in the early late Miocene.

Because of poor preservation, the Miocene/Pliocene boundary could not be detected by changes in the benthic foraminifers. Varying faunas suggesting glacial-interglacial fluctuations began in the early Pliocene *G. puncticulata* Zone and intensified during the Pliocene and Pleistocene. Two general faunal assemblages are recognized. The first is associated with hemipelagic sediment and siliceous fossils, and contains opaque benthics, several of which are typical of shallow-water environments. Shallow-water costate to striate angulogerinids suggest anoxic conditions in the source areas. The second assemblage type, associated with decreased percentages of mica, sponge spicules, and radiolarians and an increase in planktonic foraminifers, contains clearer fossils. These tend to be transparent in the Quaternary. The faunal content resembles assemblages during the Pliocene and Pleistocene at Sites 592 and 593. However, there is a large influx of *Bulimina aculeata* in these faunas during the Pliocene *G. inflata* Zone (594-6 to 594-8,CC).

Calcareous Nannoplankton

Hole 594

Core-catcher samples from 53 cores were examined for calcareous nannoplankton. Species diversity is low throughout the section and preservation ranges from moderate to good in the Pleistocene and Pliocene and moderate to poor in the Miocene. Most zonal indicators are absent. Based upon a few auxiliary zone-determining species, the following zonation was established.

The occurrence of *Emiliania huxleyi* in Samples 594-1-1, 3-4 cm to 594-6-1, 25-26 cm places this interval in the late Quaternary *Emiliania huxleyi* Zone (NN21).

Samples 594-6-3, 3-4 cm to 594-7-1, 3-4 cm are above the last occurrence of *E. ovata* in Sample 594-7,CC and are placed in the late Quaternary Zone NN20. Samples 594-7,CC to 594-11-3, 3-4 cm, above the last occurrence of *Calcidiscus macintyrei* in 594-11-5, 3-4 cm, are placed in the upper subzone of the lower Pleistocene *E. ovata* Zone (NN19b). The next marker observed is *Reticulofenestra pseudoumbilica*, whose last occurrence is in Sample 594-18-3, 3-4 cm. Therefore, Samples 594-11-5, 3-4 cm to 594-18-1, 3-4 cm are in Zones NN16/19a. Zone NN15 includes Samples 594-18-3, 3-4 cm to 594-20-5, 3-4 cm, above the last occurrence of *Amaurolithus tricorniculatus* in Sample 594-20,CC. Samples 594-20,CC to 594-23-5, 3-4 cm are placed in the combined Zones NN12/NN14. The occurrence of *Discoaster quinqueramus* in Samples 594-23,CC and 594-26-5, 3-4 cm places this interval in the late Miocene *Discoaster quinqueramus* Zone (NN11).

Samples 594-26,CC to 594-28-3, 3-4 cm, above the last occurrence of *D. hamatus* in Sample 594-28-5, 3-4 cm, are placed in the late Miocene *D. calcaris* Zone (NN10). *Discoaster hamatus* occurs in Samples 594-28-5, 3-4 cm to 594-29,CC, which places this interval in the middle Miocene *D. hamatus* Zone (NN9).

The interval from Sample 594-30-1, 3-4 cm to 594-42-3, 3-4 cm, the first occurrence of *D. kugleri*, is placed in the combined Zones NN7/NN8. The boundary between NN7 and NN8 is based upon the first occurrence of *Catinaster coalitus*, which is not present at Site 594. Samples 594-42,CC to 594-53,CC are placed in the middle Miocene *Discoaster exilis* Zone (NN6).

Hole 594A

Samples 594A-1,CC to 594A-12,CC are repeats of the section drilled at Hole 594. Samples 594A-13-3, 3-4 cm to 594-15-3, 3-4 cm, above the last occurrence of *Sphenolithus heteromorphus* in Sample 594A-15,CC, are placed in the middle Miocene *Discoaster exilis* Zone (NN6). Samples 594A-15,CC to 594-26,CC are placed in the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). Reworked Oligocene and possibly early Miocene species are present in many of the samples from this hole as well as Hole 594.

Silicoflagellates

Silicoflagellates occur throughout the Quaternary to Miocene sequence and are associated with sponge spicules and a few endoskeletal dinoflagellates. They form, however, only a minor component of the predominantly calcareous sediments.

Silicoflagellates only were investigated in detail in acid-treated core-catcher samples from Holes 594 and 594A. The assemblages found can be laced without difficulty in the northern high-latitude silicoflagellate zonation used during Leg 38 (Martini and Müller, 1976). Samples 594-6,CC to 594-16,CC belong to the *Distephanus speculum* Zone. Samples 594-18,CC to 594-20,CC seem to represent the early Pliocene *Distephanus boliviensis* Zone, although the nominate species was not found. In Samples 594-21,CC and 594-31,CC, *Mesocena circulus* was noted; consequently these samples are placed in the late middle to late Miocene *Mesocena circulus* Zone. In Sample 594-35,CC *Corbisema triacantha* was found, indicating the presence of the late early to early middle Miocene *Corbisema triacantha* Zone. The lowest sample of Hole 594 (594-53,CC) also contains *C. triacantha*, which in this sample is still associated with *M. diodon*. Thus these samples also belong in the *C. triacantha* Zone, as does Sample 594A-20,CC, because of the first occurrence of *M. diodon*. Samples 594A-21,CC to 594A-25,CC were barren of siliceous fossils.

Reworked Eocene silicoflagellates were found in most samples studied. In addition, in Sample 594-24,CC reworked Eocene diatoms (*Triceratium barbadense*) were noted.

Radiolarians

Radiolarians are rare throughout the cores recovered at Site 594, and moderately to well-preserved faunas are encountered in all cores.

Stratigraphic correlation of Neogene radiolarians at Site 594 is difficult because of the scarcity of siliceous material, the great dilution by terrigenous material, and changes of paleoenvironments. Because warm water and polar assemblages are mixed, zonations proposed for both regions have been employed.

Sections 594-1-1 to 594-6-4 contain a typical late Quaternary (less than 400,000 yr.) antarctic radiolarian assemblage that can be assigned to the *Antarctissa denticulata* Zone or Zone NR1. Common species include *A. denticulata, A. strelkovi, Theocalyptra davisiana*, and *Rhizosphaera antarctica*.

Sections 594-7-2 to 594-8-1, below the last appearance of *Stylatractus universus* in 594-7-2, are placed in Zone NR2 (Quaternary). The next marker observed was *Phormostichoartus pitomorphus*, whose last occurrence in Section 594-9-4 puts Sections 594-9-4 to 594-11-5 in Zone NR3/NR4 (early to middle Pleistocene) (the two zones are not distinguished because warmer-water species are missing).

Clathrocyclas bicornis (Hays) occurs sporadically between Sections 594-11-6 and 594-14-2. This occurrence is interpreted as reworking, because *A. denticulata* and *Theocalyptra bicornis* Popofsky were first found in Section 594-12-3. Thus Sections 594-11-6 to 594-14-4 are placed in Zone NR4.

The last consistent occurrence of *C. bicornis* (Hays) in Section 594-15-2 is used to mark the top of the Pliocene. Rare radiolarians occur in Section 594-15-2 to 594-20-3. Typical Pliocene species like *Pseudocubus vema* occur sporadically. Because of the poor preservation and scarcity of markers the interval between Sections 594-15-2 and 594-20-3 remains unzoned.

Sections 594-20-4 to 594-27-1, below the first occurrence of *Antarctissa ewingii* and above the first appearance of *Stichocorys peregrina*, are placed in the *Stichocorys peregrina* Zone (late Miocene). In the best preserved samples, forms like *Anthocyrtidium ehrenbergii* and *Hexacontium hootsi* indicate warmer conditions. Reworked specimens of Eocene to middle Miocene age occur in Sections 594-23-1 to 594-26-4.

The next markers observed were *Didymocyrtis antepenultima* and *Diartus hughesi*, whose first appearances are tabulated in Section 594-31-5. Thus, Sections 594-27-4 to 594-31-5 are placed in the *Didymocyrtis antepenultima/D. penultima* Zone. The *D. penultima* and *D. antepenultima* zones are amalgamated because the species *D. penultima* was not found in the radiolarian assemblages. Moreover, the base of the *D. penultima* Zone, which is also recognized in tropical areas at the top of the range of *Diartus hughesi*, cannot be located in Site 594 because the last occurrence of *D. hughesi* is tabulated in the *S. peregrina* Zone. It is possible that *D. hughesi* as well as *Didymocyrtis laticonus* and *D. antepenultima* have different ranges in the mid-latitude sediments. Close examinations of numerous specimens show distinct morphological differences from tropical forms (see Caulet, this volume).

Sections 594-31-6 to 594-37-1 contain poorly preserved and rare radiolarian assemblages. Barren levels occur sporadically throughout this interval, which cannot be related to a well-defined zone.

Most radiolarian species recognized in the samples below 594-37-1 are well known in the tropical assemblages of the *Diartus petterssoni* Zone (middle Miocene).

The most significant transition in the radiolarian fauna is observed between Cores 594-23 and 594-21. In Core 21 and above, most temperate or warm-water radiolarians have disappeared. Radiolarian abundances are greatly reduced and antarctic or subantarctic species become more dominant. Their occurrence suggests a northward migration of the Antarctic Convergence.

Diatoms

Diatoms are abundant to sparse in most processed samples from Site 594, except in Cores 594A-22 through 594A-26a, which are barren. In general, diatom preservation is best (fair to moderate) and diversity highest in the middle to upper Miocene. Although Pliocene–Quaternary preservation is fair and diversity low, the entire sequence contains sufficient marker species for reliable age determinations. Reworked Eocene and Oligocene diatoms are common throughout both holes.

Zonation and Sediment Age Determinations

No single zonal scheme could be employed for the entire middle Miocene–Quaternary. Migration of the Subtropical Convergence, which lies directly north of the site, has resulted in a shift in the predominance of subantarctic/antarctic to subtropical species through time. As a result, the zonal schemes employed herein are the antarctic/subantarctic zonations of Weaver and Gombos (1981) and Ciesielski (1983) and the mid-latitude zonations of Barron (1980, 1981).

The diatom assemblage suggests that the subantarctic water mass has prevailed at the site since the Miocene; therefore, the antarctic/subantarctic zonation of Ciesielski (1983) was used successfully in zonation of the entire Pliocene–Quaternary. The mixed occurrence of antarctic to mid-latitude index species in the middle to late Miocene precludes the use of a single zonal scheme for this interval. A new regional zonation is required for Site 594, utilizing the existing high to mid-latitude species, is given in Ciesielski (this volume). For the purpose of this site report, middle to late Miocene diatom zones are temporarily referred to as zonal equivalents of Barron's (1980, 1981) mid-latitude diatom zonation. It should be noted that correlations to Barron's zonation are tentative and incomplete because some index species are missing at Site 594.

In spite of difficulties in correlating with existing zonal schemes, Site 594 was reliably correlated to magnetostratigraphy by the identification of diatom datums which have been intercalibrated with magnetostratigraphy elsewhere or have been dated radiometrically. Table 3 lists these microfossil datums, their stratigraphic position, and their approximate age based upon direct correlation to magnetostratigraphy, citing diatom zones or zonal equivalents. The locations of major stratigraphic boundaries at Site 594, as determined by the application of all microfossil groups, are as follows (A indicates Hole 594A cores):

Boundary	Core-Section
Pliocene/Pleistocene	14,CC–15-2
early Pliocene/late Pliocene (unconformable boundary)	16,CC–10A-2
Miocene/Pliocene (unconformable boundary)	20-5–20-2
middle Miocene/late Miocene	38,CC–37,CC
early Miocene/middle Miocene	21,CC–20,CC

Unconformities

Four unconformities were detected within the upper Miocene through Quaternary of Holes 594 and 594A. The interval represented by each is noted here, with the evidence from Table 3. It is important to note that the Miocene/Pliocene boundary and the early/late Pliocene boundary fall within disconformities.

1. Chronozone 8–Chronozone 7, ~8.3–6.5 m.y. ago: close proximity of FAD of *H. karstenii* s.l. (Chronozone 6) in Core 24 to LAD of *D. hughesii* (basal Chronozone 8 or upper Chronozone 9) in Core 26.

2. Upper Chronozone 5–lower Gilbert Chronozone below the Sidufjall Subchronozone, ~5.4–4.5 m.y. ago (Miocene/Pliocene boundary disconformity): LAD of *C. insignis* f. *triangula* (mid to upper Chronozone 5) immediately below last constant *M. diodon* (~4.5 m.y.) in Core 20.

3. Upper Gilbert Chronozone above the Cochiti Subchronozone to upper Gauss Chronozone, ~3.85–2.7 m.y. ago: FAD of *N. weaveri* (~3.88 m.y.) immediately below LAD of *N. weaveri* (~2.64 m.y.).

4. Mid to upper Matuyama Chronozone, ~1.6–0.74 m.y. ago: occurs entirely within the *C. elliptopora/A. ingens* Zone; however, the disconformity is substantiated by the LAD of *C. bicornis* (Hays) (about 1.8 m.y.) immediately below the Brunhes/Matuyama boundary as noted by Barton and Bloemendal (this volume).

Table 3. Major biostratigraphic and magnetostratigraphic datums observed in Holes 594 and 594A (diatoms and radiolarians).

Datum	Occurrence of datum in hole (Core-Section, interval in cm)	Age of datums (m.y.)
LAD *Stylatractus universus*	7-1 to 6-4	425,000 yr.
Brunhes/Matuyama boundary	11-5, 75–77	730,000 yr.
Matuyama Chronozone disconformity	~11-5	~1.6–~0.74
LAD *Clathrocyclas bicornis* (Hays)	11-6	
Last consistent *C. bicornis*	15-2 to 14-2	?1.8
LAD *Coscinodiscus kolbei*	15-2 to 13-5	1.89
LAD *Cosmiodiscus insignis*	16-2 to 15-5	2.50
FAD *Theocalyptra davisiana*	16-4	2.8–2.6
LAD *Coscinodiscus vulnificus*	16-2 to 15-5	2.22
LAD *Nitzschia weaveri*	10A-2 to 16-5	2.64
upper Gilbert–upper Gauss Chronozone disconformity	10A-2 to 16-5	~3.85–2.70
FAD *Nitzschia weaveri*	10A-5 to 10A-2	3.88
LAD *Stichocorys peregrina*	19-1	4.6–4.4
last consistent *Mesocena diodon*	20-2 to 19-5	4.45
Chronozone 5–lower Gilbert disconformity	20-5 to 20-2	~5.4 to ~4.5
LAD *Cosmiodiscus insignis* f. *triangula*	20-5 to 20-2	5.4
LAD *Asteromphalus* sp. 1	21-5 to 21-2	~5.6
FAD *C. insignis* f. *triangula*	23-2 to 11A-5	late Chron 6 (~6.0)
FAD *Nitzschia reinholdii*	23-5 to 23-2	early Chron (~6.4)
Last consistent *Mesocena circulus*	23-5 to 23-2	early Chron 6 (~6.4)
FAD *Hemidiscus karstenii* f. 1	24-5 to 24-5	mid to early Chron 6
Chronozone 8–Chronozone 7 disconformity	26-2 to 24-5 (exact location of hiatus not yet determined)	~8.5–6.5
LAD *Diartus hughesi*	—— to 26-2	~8.5
FAD *Stichocorys peregrina*	—— to 27-1	~8.5
LAD *Thalassionema hirosakensis*	29 to 28-5	
LAD *Lithodesmium reynoldsii*	30 to 29	~Chron 9/Chron 8 boundary
LAD *Cyrtocapsella japonica*	—— to 31-2	~8.7
FAD *Asteromphalus* sp. 1	31-5 to 31-2	~8.7
FAD *D. hughesi*	—— to 31-5	~8.7
FAD *Didymocyrtis antepenultima*	—— to 31-5	
Last consistent *Denticulopsis lauta*	35-5 to 35-2	late Chron 9 (~8.7–8.5)
Last common *Denticulopsis dimorpha*	39-1 to 38-1	10.2
LAD *Nitzschia denticuloides*	44-1 to 43-1	early Chron 10
FAD *Denticulopsis dimorpha*	46-2 to 45-2	11.1
LAD *Coscinodiscus lewisianus*	52-2 to 51-1	late Chron 13 (~12.5–12.6)
LAD *Denticulopsis nicobarica*	18A-1 to 17A-2	late Chron 14 (~12.8)
FAD *Denticulopsis praedimorpha*	19A-2 to 18A-1	earliest Chron 14 (~13.3?)
FAD *Denticulopsis hustedtii*	19A-2 to 18A-1	mid Chron 15 (~14.3?)
FAD *Brunia mirabilis*	19A-2 to 18A-1	

Note: A indicates cores from Hole 594A.

PALEOMAGNETISM

The two most notable paleomagnetic results were the location of the Brunhes/Matuyama boundary at 99 m sub-bottom depth, and the surprisingly low intensities of magnetization, given the higher terrigenous input at this site.

HPC cores from Holes 594 and 594A were sampled at 50 cm intervals. The XCB cores from Hole 594A were sampled at 150 cm intervals. Absolute orientations were obtained for only four cores from Hole 594. Laboratory NRM and low-field magnetic susceptibility measurements have been completed for most of Hole 594 (Table 4). The relatively high negative mean inclination is largely due to the preponderance of normal directions during the Brunhes.

Table 4. Preliminary NRM and magnetic susceptibility data for Hole 594.

Geometric mean intensity	0.072 μG
Scalar mean inclination (+ 1 s.d.)	− 20.7° + 38.4°
Axial dipole inclination	− 63.8°
Mean angle between repeats	15.4° (34 repeats)
NRM intensity variation	
0–10 m	High (0.1 to 10 μG, typically)
10–200 m	Intermediate (~0.1 μG)
200–350 m	Low (0.01 to 0.1 μG)
Below 350 m	Medium to low (0.01 to 0.3 μG)
Susceptibility variation	
0–108 m	Alternating peaks and troughs
0–30 m	Intermediate (5 to 25 μG Oe^{-2} typically)
30–179 m	Low (1 to 10 μG Oe^{-1})
179–184 m	Very low (0 to 1 μG Oe^{-1})
184–399 m	Weak diamagnetic
399–488 m	Low (0 to 2 μG Oe^{-1})

Alternating peaks and troughs in magnetic susceptibility occur within the first 12 cores (0–108 m sub-bottom depth). Depths of the most prominent peaks are shown in Table 5 and generally coincide with higher intensities of magnetization. These variations have not yet been carefully compared with the lithologic variations during the Quaternary. However, it was noted that in the upper part of the sequence, where the alternating dark, fine-grained and light, coarser-grained sediments are most pronounced, the darker-colored sediments are characterized by higher NRM. Deeper in the sequence this contrast in NRM disappears well before the color zonations disappear. This suggests that gradual diagenesis of magnetic minerals of terrigenous origin is occurring on a time scale on the order of 10^5 yr.

Table 5. Prominent peaks in magnetic susceptibility, Hole 594.

Core-Section (level in cm)	Sub-bottom depth (m)	Susceptibility (μG Oe^{-1})
1-4, 025	4.75	41.3
2-2, 125	8.65	29.6
3-3, 075	19.25	239.2
4-1, 125	26.35	64.2
4-3, 025	28.35	249.2
15-1, 025	130.95	11.2
16-2, 075	142.55	11.2
46-2, 025	430.05	10.3

No very thin, surficial, high-intensity layer was found in Hole 594. The general pattern of intensity variations is also shown in Hole 594. The general pattern of intensity variations is also shown in Table 4. A region of uniformly high intensity during the Miocene which was observed at previous sites was also not present.

A magnetic polarity stratigraphy based on NRM results for Hole 594 is presented in Figure 10. There is convincing evidence that the Brunhes/Matuyama boundary occurs within Core 594-11. Below this, the interpretation is less certain. A possible alternative to the illustrated (preferred) scheme is to assign the top of the Gauss Chron to the depth where the top of the Olduvai Subchron is illustrated. The Olduvai Subchron would then replace the Jaramillo in the figure. However, this interpretation is in poorer agreement with the diatom and radiolarian stratigraphy and is less probable. Below the top of the Gauss, directions are too scattered for polarity intervals to be resolved with any degree of confidence. There are some fairly long intervals with a predominantly normal inclination bias, which is indicative of partial secondary overprinting during the Brunhes Chron—probable because viscous remanence built up in fine-grained iron monosulfides.

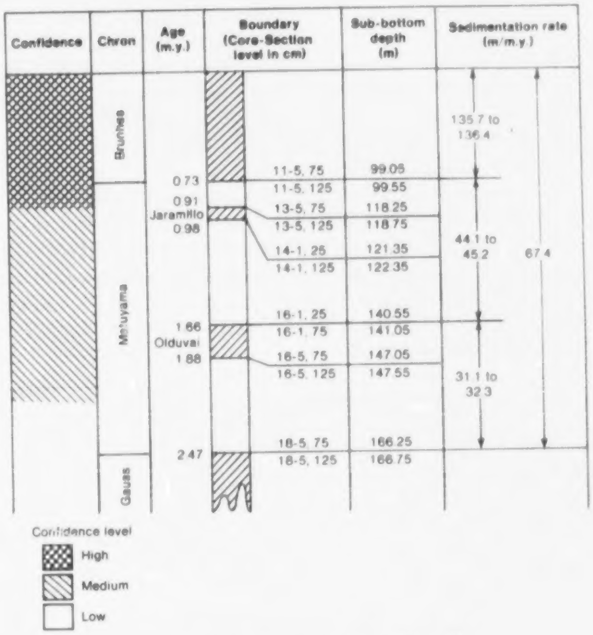


Figure 10. Magnetic polarity stratigraphy for Hole 594.

Results of partial AF demagnetization tests conduced on the *Glomar Challenger* on three sediment samples from the Brunhes Chron are summarized in Table 6. A viscous component amounting to 10 to 20% of the natural remanence was detected. The results show that these upper sediments preserve a stable primary remanence which dominates the NRM. As in previous sites, there is a strong case for arguing that the deterioration of the paleomagnetic record with depth is caused by a combination of very gradual diagenetic alteration of primary magnetic minerals (in a sulfur-rich environment) and compaction effects. In materials with a sufficiently large number of uniformly distributed magnetic grains, gradual compaction into a closer-packed structure will cause dispersion of the directions of remanence of individual

Table 6. Summary of progressive AF demagnetization data for three samples within the upper, long normal zone, Hole 594.

Core-Section (level in cm)	Sub-bottom depth (m)	J_0 (μG)	Stable range (Oe)	ΔI
1-4, 75	5.25	3.686	0-600	± 15°
5-4, 75	39.95	1.194	0-400	± 15°
6-3, 75	48.05	0.970	0-400	± 12°

Note: J_0 = NRM intensity. Stable Range is the range of peak demagnetizing field within which only small changes in direction occur, ΔI is the inclination change in this stable range.

grains without changing the statistical mean direction. The magnitude of the resultant magnetization will, of course, be less. When the density of magnetic grains falls to sufficiently low values, statistical averaging of the dispersed directions will no longer give the original mean, and the resultant directions of magnetization of specimens will become scattered.

As noted in the paleomagnetic report for Site 591, there was a marked decrease in magnetization after storage by a factor of two to three. Repeat measurements conducted on board the *Glomar Challenger* showed that most of these decays occur during the first 36 hr. of storage. The problem is a serious one which requires detailed investigation.

SEDIMENTATION RATES

Sedimentation rates are calculated upon the diatom and radiolarian datum ages provided in Table 3. The ages of the datums have been determined by intercalibration with magnetostratigraphy elsewhere. In most cases, the stratigraphic level of the datum is known only within certain depth limits, and hence the midpoint is used in the plot (Fig. 11).

Sedimentation rates were high (76–78 m/m.y.) during much of the middle and late Miocene during deposition of foraminifer-bearing nannofossil ooze and nannofossil ooze. Unlike nearly all of the sites drilled further north during Leg 90, rates at Site 594 (~ 30–40 m/m.y.) were relatively low during the latest Miocene and Pliocene, an interval punctuated by 3 disconformities. Rates of deposition began to increase dramatically at the base of the Pleistocene, were high during the early Pleistocene (late Matuyama chron; 89 m/m.y.) and even higher (avg. 138 m/m.y.) during the last 700,000 yr. (Brunhes Chron). Therefore, there are three broad, stratigraphic intervals marked by differing rates of sedimentation: intermediate rates during much of the middle and late Miocene, lowest rates during the latest Miocene and Pliocene, and highest rates during the Pleistocene.

SUMMARY AND CONCLUSIONS

Site 594 is located at the southern margin of the Chatham Rise east of the South Island of New Zealand, in a water depth of 1204 m at a position of 45°31.41′S, 174°56.88′E. The site lies in the subantarctic water mass immediately south of the Subtropical Convergence, and is the southernmost of a series of sites forming a north-

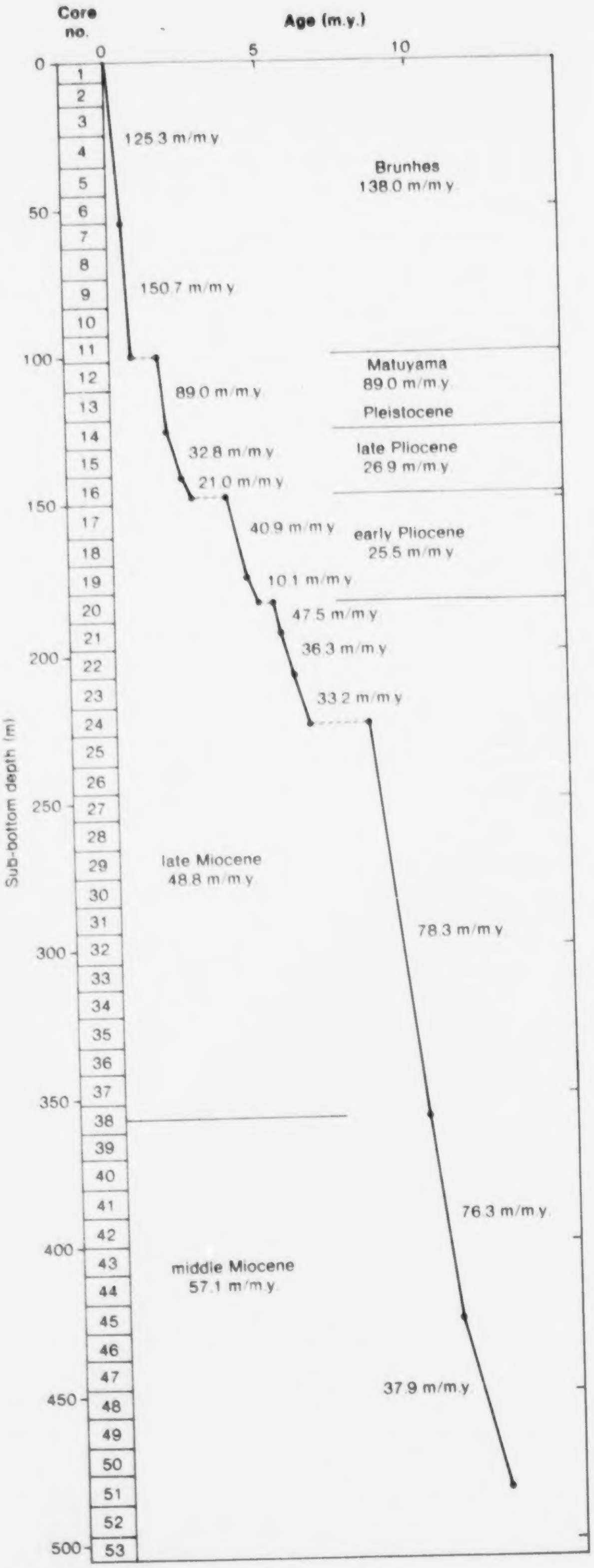


Figure 11. Sedimentation rates for Site 594.

south transect. It is situated in a transitional region between oceanic and terrigenous influences, thus differing from all other sites on the southwest Pacific transect. It is located on a relatively flat, smooth seafloor, underlain by what appears to be a simple seismic stratigraphy of parallel reflectors.

Site 594 consists of three holes cored to a maximum sub-bottom depth of 639.5 m. Excellent core recovery was obtained from 0 to 207.5 m sub-bottom depth (Holocene to latest Miocene) using the HPC to about 130 m in Holes 594 and 594A. The remaining section was rather poorly recovered using the XCB.

The section extends from the latest early Miocene to the Holocene and is cut by at least four unconformities. A paleomagnetic stratigraphy has been identified down to the late part of the Gauss Chron (about 2.5 m.y. ago).

The sequences are assigned to two lithostratigraphic units, the lower one of which is subdivided into two subunits (Fig. 12). Divisions are based mainly upon differences in composition that are clearly revealed in the color changes.

Unit I, of earliest Pliocene to Quaternary age, consists of an alternating sequence of pelagic and hemipelagic lithofacies generally defined by bluish gray and greenish gray sediment, respectively. Pelagic–hemipelagic cycles range in thickness from 0.5 to 10 m. Contacts between lithofacies are completely gradational, subtle variations in color between the bluish gray and greenish gray end-members.

The pelagic lithofacies consists mainly of blue gray foraminifer-bearing nannofossil ooze, foraminifer- and clay-bearing nannofossil ooze, or foraminifer-bearing clayey nannofossil ooze. The lithofacies is dominated by calcareous nannofossils, with rare to common foraminifers and clay minerals, and trace and rare amounts of quartz, feldspars, mica, and biogenic siliceous components that include sponge spicules, diatoms, and radiolarian fragments.

The hemipelagic lithofacies consists of a variety of sediment intergrades between a clay- and silt-bearing nannofossil ooze and a nannofossil-bearing clayey silt; this greenish gray lithofacies is commonly diatom- and sponge-spicule-bearing, and rarely foraminifer-bearing. Dominant components are varying quantities of calcareous nannofossils, clay minerals, and silt-sized grains of quartz, feldspar, and mica. Foraminifers and siliceous biogenic components are rare to common. Compared to the pelagic lithofacies, the sediment is relatively enriched in both terrigenous silt and clay and in biogenic siliceous components, notably sponge spicules and diatoms, with relative depletion of both foraminifers and nannofossils. A few volcanic ash layers are present.

The contact between Units I and II is gradational over several meters, but is recognized by the change from interbedded pelagic and hemipelagic facies of Unit I to a pelagic facies in Unit II. Unit II, of late early Miocene to earliest Pliocene age, is mainly a foraminifer-bearing nannofossil ooze (chalk) to nannofossil ooze (chalk). Separate ooze and chalk subunits are defined, the ooze/chalk transition occurring at about 466 m in Hole 594.

Subunit IIA, of early middle Miocene to earliest Pliocene age, is a light gray foraminifer-bearing nannofossil ooze that grades down into a nannofossil ooze near 245 m sub-bottom depth. Calcareous nannofossils dominate the components; foraminifers are generally common above 245 m but form only trace to rare amounts below this level.

Subunit IIB, of late early to early middle Miocene age, is a light gray nannofossil chalk with occasional interbeds of olive gray silt-bearing clayey nannofossil chalk below 534 m sub-bottom; these are interpreted as turbidite layers. Below 467 m sub-bottom depth (early middle Miocene), distinctive pale to dark green laminae occur commonly in the subunit. The laminae may represent altered volcanic glass.

The turbidite interbeds range in thickness from a few to 90 cm, have sharp erosional bases, are normally graded, and have burrowed gradational tops that grade upward into overlying chalk. They are dominated by calcareous nannofossils with common micas and clay minerals, rare foraminifers, and occasional quartz and feldspar grains. Textures range from medium to very fine silt at the base of beds to clay-dominated at the top. There is a pronounced habitat stratification in the infaunal burrow types in the thicker beds in the upper portion of units, with Planolites between 0 and about 5 cm, Chondrites to depths of 10 cm, and Zoophycos to depths of 15 to 20 cm in the beds.

Site 594 has much paleoceanographic potential. There is a fine biostratigraphic sequence of subantarctic elements from the middle Miocene to the Holocene. Both calcareous and siliceous microfossil groups are well represented. The calcareous nannoplankton assemblages are typical of cold water and largely lack the warm-water forms so useful in biostratigraphic zonations. Considerable microfossil reworking, particularly with respect to foraminifers, was observed associated with the early middle Miocene turbidites.

The latest Miocene to Holocene sequence of oscillations between dark hemipelagic and lighter pelagic biogenic sediments is climatically related. The pelagic episodes mark climatic warmings and high sea levels (interglacials). These have little biosiliceous sediment, less calcareous dissolution, and warmer-water planktonic foraminifer faunas. The hemipelagics mark cooler (glacial) episodes when low stands of sea level led to major sediment bypassing over the continental shelves and the deposition of terrigenous materials in the basins surrounding New Zealand. These episodes exhibit cold-water planktonic foraminiferal faunas, rich siliceous microfossil assemblages, and much carbonate dissolution. Intergrades occur between these two extremes. Twenty-five major hemipelagic episodes have occurred during that interval represented by sediments in the last 6 m.y. The oldest coincides with the well-known Kapitean (Messinian) regression.

A distinct increase in radiolarian abundances occurs during the latest Miocene in response to the important paleoceanographic changes then; perhaps it is related to the development of the Subtropical Convergence.

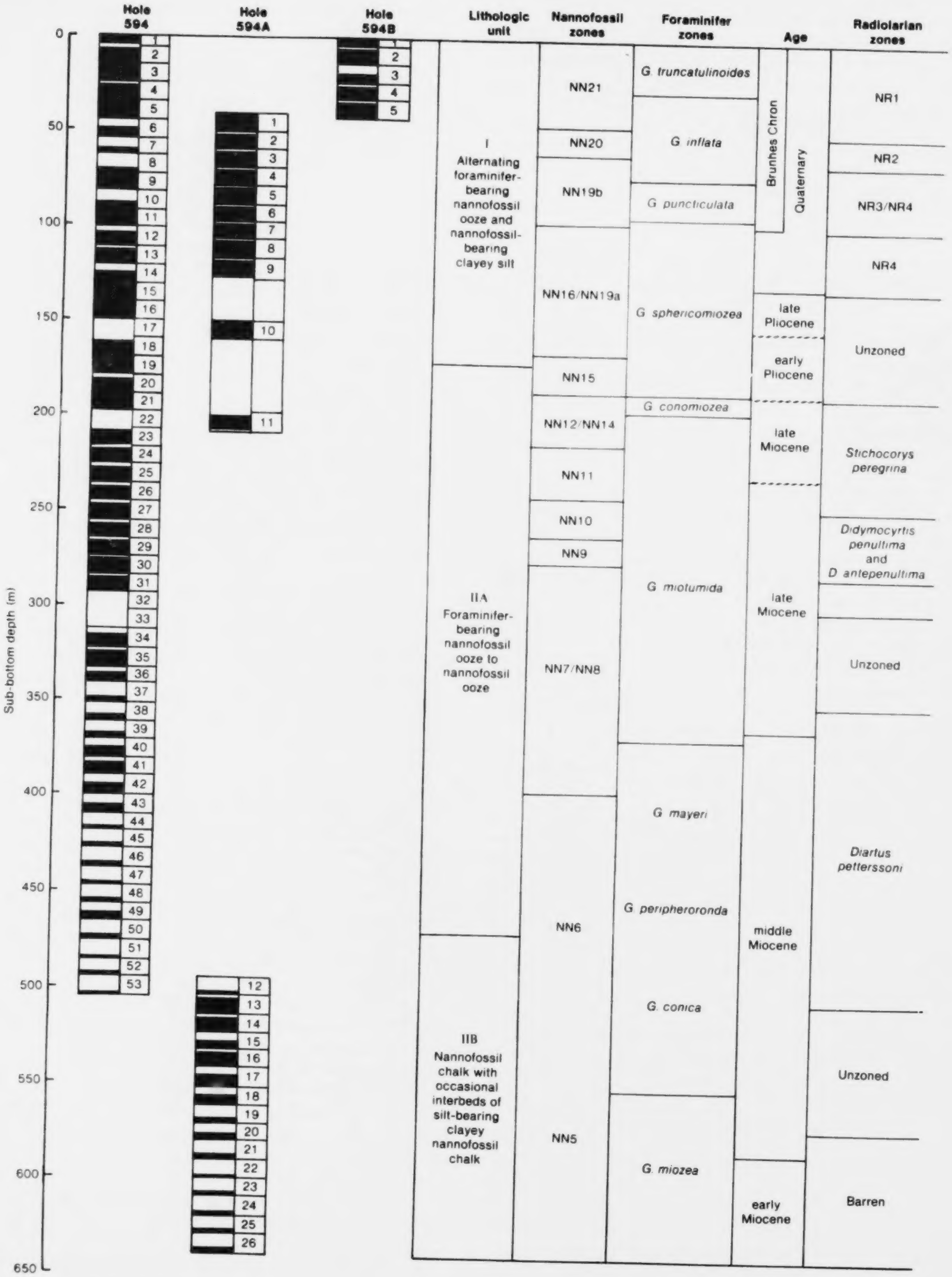


Figure 12. Summary lithology, biostratigraphy, and mass accumulation rates for Site 594. Core recovery shown in black.

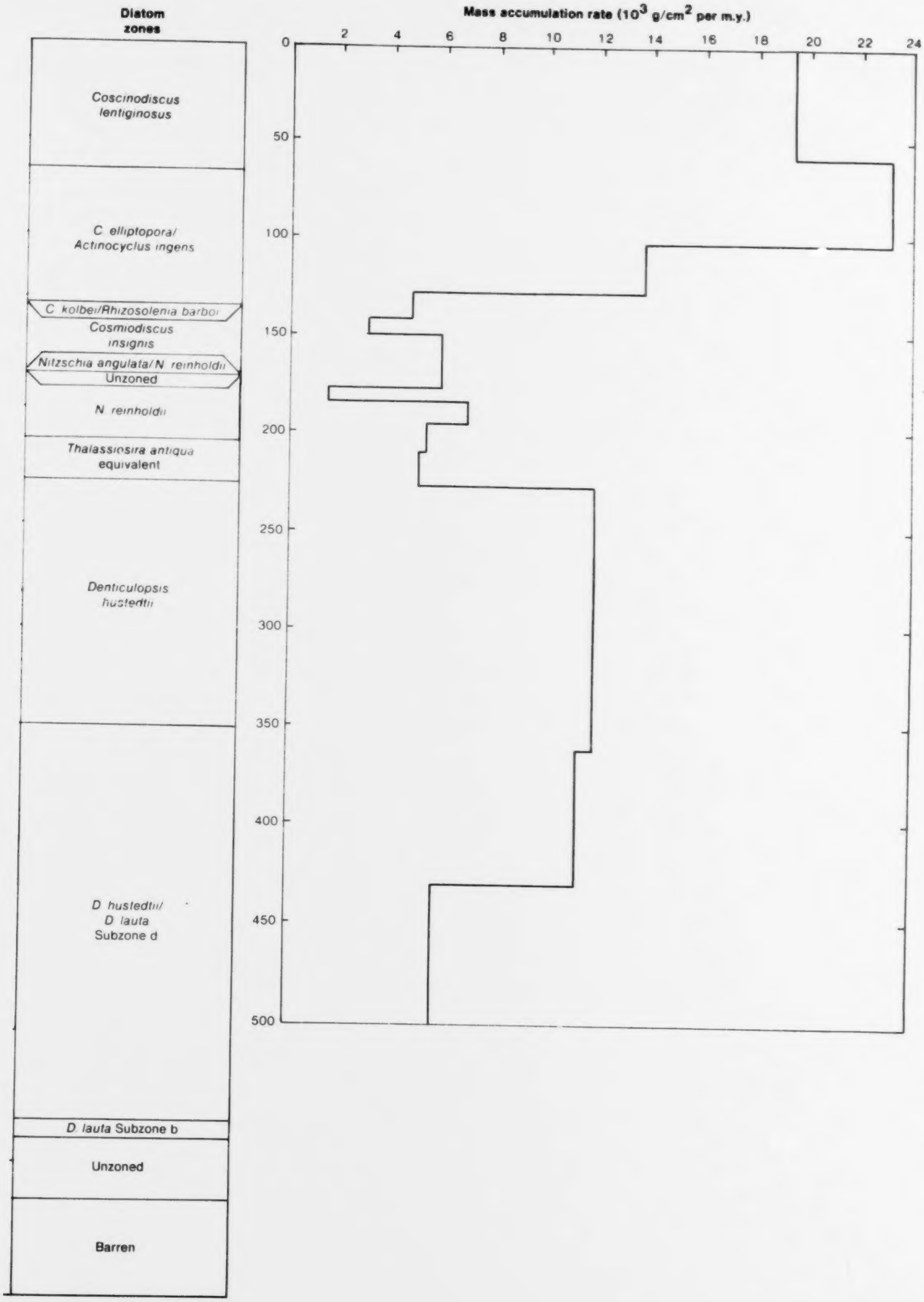


Figure 12. (Continued).

REFERENCES

Ballance, P. F., 1976. Evolution of the upper Cenozoic magmatic arc and plate boundary in northern New Zealand. *Earth Planet. Sci. Lett.*, 28:356-370.

Barron, J. A., 1980. Lower Miocene to Quaternary diatom biostratigraphy of DSDP Leg 57, off northeastern Japan, Deep Sea Drilling Project. *In* Scientific Party, *Init. Repts. DSDP*, 56, 57, Pt. 2: Washington (U.S. Govt. Printing Office), 641-686.

________, 1981. Late Cenozoic diatom biostratigraphy of the middle-latitude eastern North Pacific, Deep Sea Drilling Project Leg 63. *In* Yeats, R. S., Haq, B. U., et al., *Init. Repts. DSDP*, 63: Washington (U.S. Govt. Printing Office), 507-538.

Carter, R. M., and Norris, R. J., 1976. Cenozoic history of southern New Zealand: an accord between geological observations and plate tectonic predictions. *Earth Planet. Sci. Lett.*, 31:85-96.

Ciesielski, P. F., 1983. The Neogene and Quaternary diatom biostratigraphy of subantarctic sediments, Deep Sea Drilling Project Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71, Pt. 2: Washington (U.S. Govt. Printing Office), 635-665.

Cullen, D. J., 1976. Sediment transport on the continental shelf of Otago: a reinterpretation of so-called relict features. *N.Z. J. Geol. Geophys.*, 9:527-534.

Griggs, G. B., Canter, L., Kennett, J. P., and Carter, R. V., 1983. Late Quaternary marine stratigraphy southeast of New Zealand. *Geol. Soc. Am. Bull.*, 94:791-797.

Mammerickx, J. L., Chase, T. E., Smith, S. M., and Taylor, I. L., 1974. *Bathymetry of the South Pacific*. IMR Technical Reports, Scripps Institution of Oceanography, La Jolla, California.

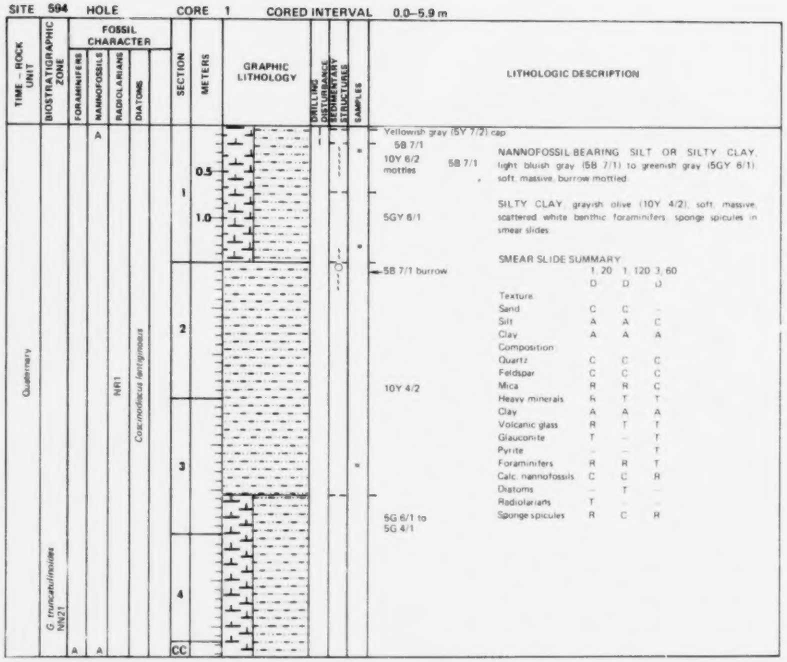
Martini, E., and Müller, C., 1976. Eocene to Pleistocene silicoflagellates from the Norwegian-Greenland Sea (DSDP Leg 38). *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP*, 38: Washington (U.S. Govt. Printing Office), 857-896.

Nelson, C. F., and Hume, T. M., 1978. Relative intensity of tectonic events revealed by the Tertiary sedimentary record in the North Wangianui Basin and adjacent areas, New Zealand. *N.Z. J. Geol. Geophys.*, 20:369-392.

Weaver, F. M., and Gombos, A. M., 1981. Southern high latitude diatom biostratigraphy. *In* Warme, T. E., Douglas, R. C., and Winterer, E. L. (Eds.), *The Deep Sea Drilling Project: A Decade of Progress*. Soc. Econ. Paleont. Mineral. Spec. Publ., 32:445-470.

Date of Acceptance: 3 December 1983

SITE 594 HOLE CORE 1 CORED INTERVAL 0.0–5.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides NN21
A
A
A
NR1
Coscinodiscus lentiginosus
1
2
3
4
CC
0.5
1.0
Yellowish gray (5Y 7/2) cap
5B 7/1
10Y 6/2 mottles
5B 7/1
5GY 6/1
5B 7/1 burrow
10Y 4/2
5G 6/1 to 5G 4/1

LITHOLOGIC DESCRIPTION

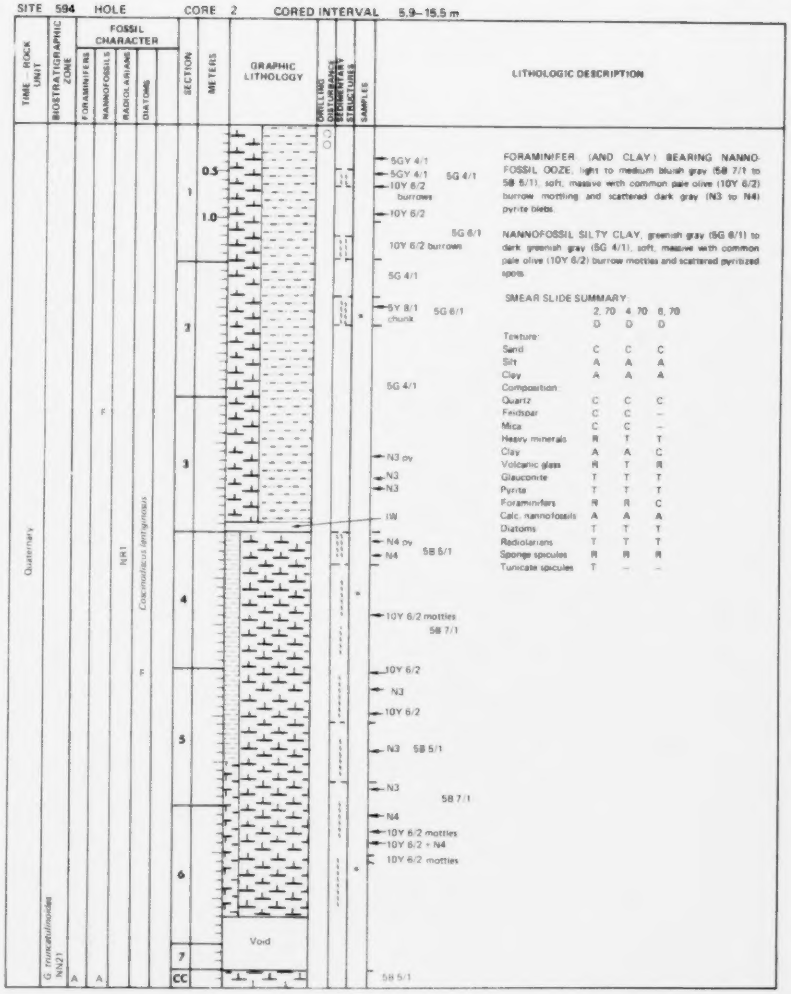
NANNOFOSSIL BEARING SILT OR SILTY CLAY, light bluish gray (5B 7/1) to greenish gray (5GY 6/1) soft, massive, burrow mottled.

SILTY CLAY, grayish olive (10Y 4/2), soft, massive, scattered white benthic foraminifers, sponge spicules in smear slides.

SMEAR SLIDE SUMMARY:

	1, 20	1, 120	3, 60
	D	D	D
Texture:			
Sand	C	C	–
Silt	A	A	C
Clay	A	A	A
Composition:			
Quartz	C	C	C
Feldspar	C	C	C
Mica	R	R	C
Heavy minerals	R	T	T
Clay	A	A	A
Volcanic glass	R	T	T
Glauconite	T	–	T
Pyrite	–	–	T
Foraminifers	R	R	T
Calc. nannofossils	C	C	R
Diatoms	–	T	–
Radiolarians	T	–	–
Sponge spicules	R	C	R

SITE 594 HOLE CORE 2 CORED INTERVAL 5.9–15.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides NN21
A
A
F
NR1
Coscinodiscus lentiginosus
F
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5GY 4/1
5GY 4/1
5G 4/1
10Y 6/2 burrows
10Y 6/2
5G 6/1
10Y 6/2 burrows
5G 4/1
5Y 8/1 chunk
5G 6/1
5G 4/1
N3 py
N3
N3
IW
N4 py
N4
5B 5/1
10Y 6/2 mottles
5B 7/1
10Y 6/2
N3
10Y 6/2
N3
5B 5/1
N3
5B 7/1
N4
10Y 6/2 mottles
10Y 6/2 + N4
10Y 6/2 mottles
5B 5/1

LITHOLOGIC DESCRIPTION

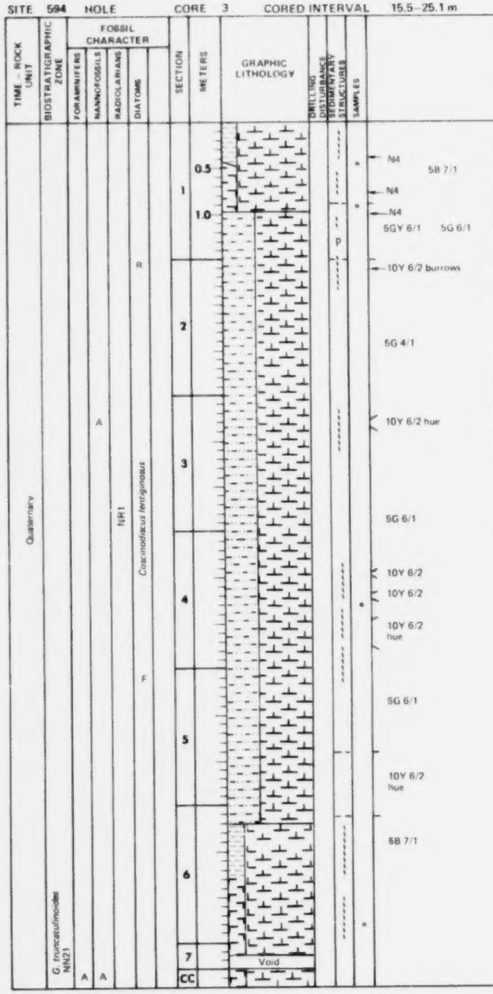
FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, light to medium bluish gray (5B 7/1 to 5B 5/1), soft, massive with common pale olive (10Y 6/2) burrow mottling and scattered dark gray (N3 to N4) pyrite blebs.

NANNOFOSSIL SILTY CLAY, greenish gray (5G 6/1) to dark greenish gray (5G 4/1), soft, massive with common pale olive (10Y 6/2) burrow mottles and scattered pyritized spots.

SMEAR SLIDE SUMMARY:

	2, 70	4, 70	6, 70
	D	D	D
Texture:			
Sand	C	C	C
Silt	A	A	A
Clay	A	A	A
Composition:			
Quartz	C	C	C
Feldspar	C	C	–
Mica	C	C	–
Heavy minerals	R	T	T
Clay	A	A	C
Volcanic glass	R	T	R
Glauconite	T	T	T
Pyrite	T	T	T
Foraminifers	R	R	C
Calc. nannofossils	A	A	A
Diatoms	T	T	T
Radiolarians	T	T	T
Sponge spicules	R	R	R
Tunicate spicules	T	–	–

SITE 594 HOLE CORE 3 CORED INTERVAL 15.5–25.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. truncatulinoides
NN21
A
A
A
NR1
R
Coscinodiscus lentiginosus
F
1
2
3
4
5
6
7
CC
0.5
1.0
Void
P
N4
5B 7/1
N4
N4
5GY 6/1
5G 6/1
10Y 6/2 burrows
5G 4/1
10Y 6/2 hue
5G 6/1
10Y 6/2
10Y 6/2
10Y 6/2 hue
5G 6/1
10Y 6/2 hue
5B 7/1

LITHOLOGIC DESCRIPTION

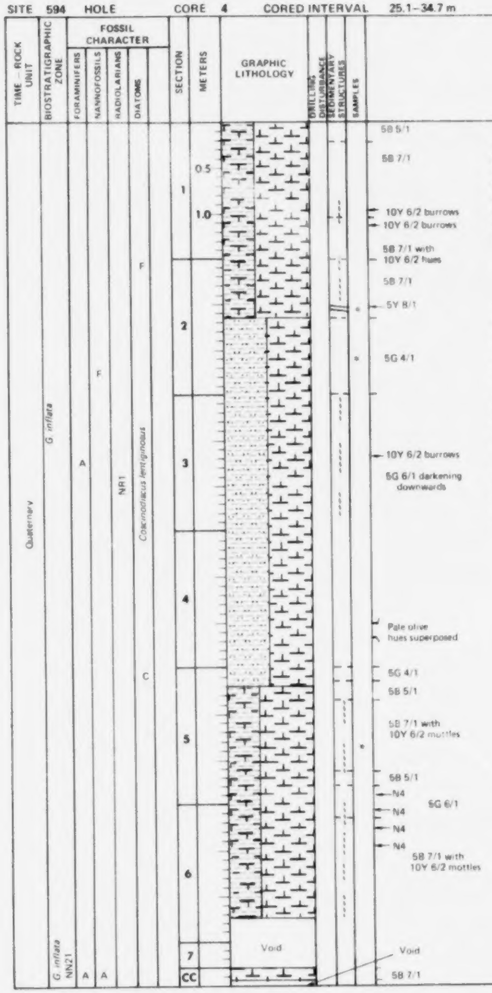
FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1), soft but firm, massive with pale olive (10Y 6/2) hues and burrow mottles throughout, some pyrite specks.

CLAY AND SILT BEARING NANNOFOSSIL OOZE, soft to firm, dark greenish gray (5G 4/1) to greenish gray (5G 6/1), massive with pale olive (10Y 6/2) hues and burrows, alternates with FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, all color boundaries gradational.

SMEAR SLIDE SUMMARY

	1, 49 D	1, 95 M	4, 77 D	6, 128 D
Texture:				
Sand	C	R	C	C
Silt	A	A	A	A
Clay	A	A	A	A
Composition:				
Quartz	R	–	C	C
Feldspar	–	–	T	–
Heavy minerals	T	T	T	T
Clay	–	C	C	C
Volcanic glass	–	T	R	R
Glauconite	–	–	T	–
Pyrite	T	C	T	T
Foraminifers	C	R	R	C
Calc. nannofossils	A	A	A	A
Diatoms	T	T	T	T
Radiolarians	T	T	T	T
Sponge spicules	R	R	R	R

SITE 594 HOLE CORE 4 CORED INTERVAL 25.1–34.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. inflata
G. inflata
NN21
A
A
F
A
A
NR1
F
Coscinodiscus lentiginosus
C
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5B 5/1
5B 7/1
10Y 6/2 burrows
10Y 6/2 burrows
5B 7/1 with 10Y 6/2 hues
5B 7/1
5Y 8/1
5G 4/1
10Y 6/2 burrows
5G 6/1 darkening downwards
Pale olive hues superposed
5G 4/1
5B 5/1
5B 7/1 with 10Y 6/2 mottles
5B 5/1
N4
N4
N4
N4
5G 6/1
5B 7/1 with 10Y 6/2 mottles
Void
5B 7/1

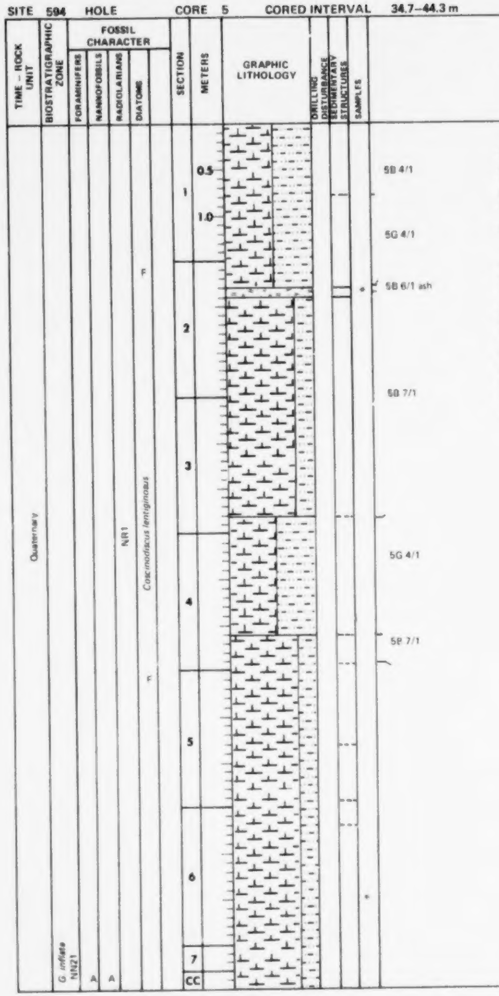
LITHOLOGIC DESCRIPTION

FORAMINIFER AND CLAY BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1) to medium bluish gray (5B 5/1), soft but firm, massive with common burrow mottling in pale olive (10Y 6/2) colors, diffuse boundaries, alternates with CLAYEY SILTY NANNOFOSSIL OOZE, greenish gray (5G 6/1) to dark greenish gray (5G 4/1), soft but firm, massive with pale olive (10Y 6/2) burrow mottles and hues, scattered dark gray (N4) pyrite.

SMEAR SLIDE SUMMARY

	2, 59 M	2, 114 D	5, 84 D
Texture:			
Sand	R	C	–
Silt	C	A	–
Clay	D	A	–
Composition:			
Quartz	R	A	R
Feldspar	T	–	T
Heavy minerals	T	T	T
Clay	C	A	–
Volcanic glass	T	R	R
Glauconite	–	T	–
Pyrite	T	R	T
Foraminifers	R	R	C
Calc. nannofossils	A	A	A
Diatoms	T	R	T
Radiolarians	T	T	T
Sponge spicules	R	R	T
Undefined, too small (clay?)	–	–	C

SITE 594 HOLE CORE 5 CORED INTERVAL 34.7–44.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. inflata
NN21
A
A
NR1
F
Coscinodiscus lentiginosus
F
1
2
3
4
5
6
7
CC
0.5
1.0
5B 4/1
5G 4/1
5B 6/1 ash
5B 7/1
5G 4/1
5B 7/1

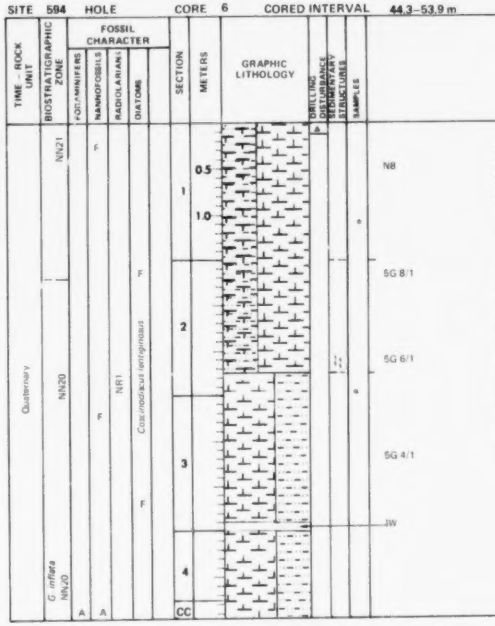
LITHOLOGIC DESCRIPTION

CLAYEY QUARTZOSE NANNOFOSSIL OOZE, dark gray and dark green (5B 5/1 and 5G 4/1) alternating with CLAYEY NANNOFOSSIL OOZE, light and very light gray (5B 7/1, 5G 8/1, 5B 8/1). Contacts are gradational. Only one megascopic ash

SMEAR SLIDE SUMMARY

	2, 35	6, 102
	M	D
Composition:		
Quartz	R	R
Feldspar	T	–
Heavy minerals	–	T
Clay	C	A
Volcanic glass	D	R
Pyrite	T	T
Foraminifers	–	R
Calc. nannofossils	R	A
Diatoms	T	T
Radiolarians	T	T
Sponge spicules	T	T

SITE 594 HOLE CORE 6 CORED INTERVAL 44.3–53.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN21
NN20
G. inflata
NN20
F
F
A
A
NR1
F
Coscinodiscus lentiginosus
F
1
2
3
4
CC
0.5
1.0
A
N8
5G 8/1
5G 6/1
5G 4/1
IW

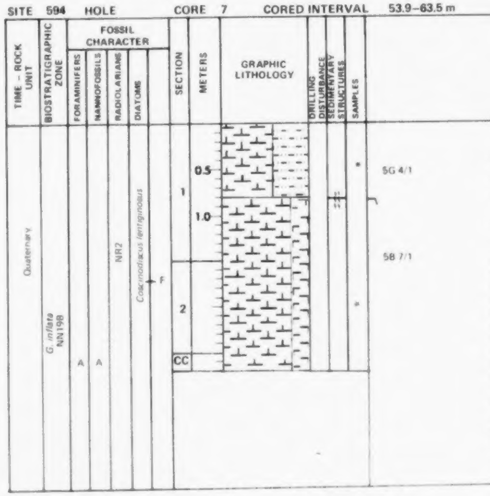
LITHOLOGIC DESCRIPTION

FORAMINIFER- AND CLAY(?)-BEARING NANNOFOSSIL OOZE (N8), homogeneous with color grading down into light greenish grays (5G 8/1 to 5G 6/1) overlying CLAY-, QUARTZ-, and MICA-BEARING NANNOFOSSIL OOZE, dark green (5G 4/1), homogeneous throughout.

SMEAR SLIDE SUMMARY:

	1, 112	2, 148
	D	D
Texture:		
Sand	R	R
Silt	A	A
Clay	D	A
Composition:		
Quartz	R	C
Feldspar	T	T
Mica	–	C
Clay	C	C
Volcanic glass	R	R
Glauconite	–	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	A
Diatoms	T	T
Sponge spicules	T	T

SITE 594 HOLE CORE 7 CORED INTERVAL 53.9–63.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. inflata
NN19B
A
A
NR2
Coscinodiscus lentiginosus
F
1
2
CC
0.5
1.0
5G 4/1
5B 7/1

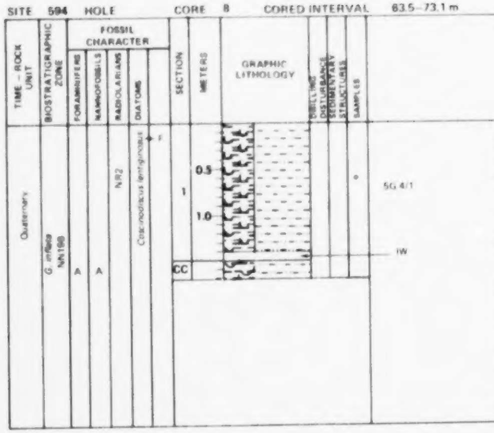
LITHOLOGIC DESCRIPTION

MICA- AND QUARTZ-BEARING NANNOFOSSIL OOZE, dark greenish (5G 4/1), homogeneous, H_2S-rich, pyrite-rich grading down into FORAMINIFER-BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1), firm, stained slightly with yellowish iron oxide

SMEAR SLIDE SUMMARY

	1, 30	2, 94
	D	D
Texture:		
Sand	R	–
Silt	A	A
Clay	A	D
Composition:		
Quartz	C	R
Feldspar	T	T
Mica	C	–
Heavy minerals	T	–
Clay	R	–
Volcanic glass	R	R
Pyrite	T	–
Foraminifers	R	C
Calc. nannofossils	A	A
Diatoms	R	T
Radiolarians	T	T
Sponge spicules	R	T

SITE 594 HOLE CORE 8 CORED INTERVAL 63.5–73.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. inflata
NN19B
A
A
NR2
Coscinodiscus lentiginosus
F
1
0.5
1.0
CC
5G 4/1
IW

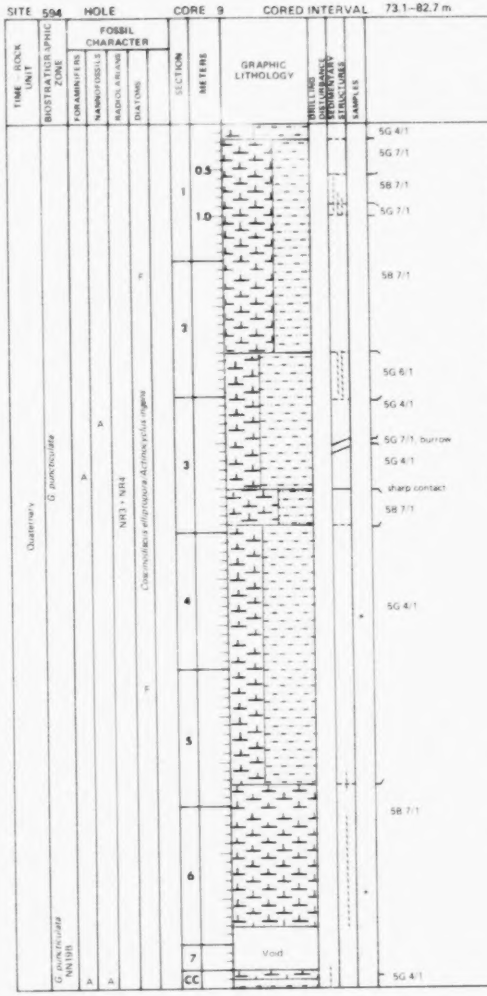
LITHOLOGIC DESCRIPTION

DIATOM, SPONGE SPICULE, NANNOFOSSIL, AND FORAMINIFER-BEARING SILT, dark greenish gray (5G 4/1), homogeneous, H_2S-rich, micaceous, gritty texture.

SMEAR SLIDE SUMMARY

	1, 60
	D
Texture	
Sand	C
Silt	A
Clay	A
Composition	
Quartz	C
Feldspar	T
Mica	C
Volcanic glass	R
Pyrite	T
Foraminifers	C
Calc. nannofossils	C
Diatoms	C
Radiolarians	T
Sponge spicules	C

SITE 594 HOLE CORE 9 CORED INTERVAL 73.1–82.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
G. puncticulata
G. puncticulata
NN19B
A
A
A
A
NR3 + NR4
Coscinodiscus elliptopora/Actinocyclus ingens
F
F
1
0.5
1.0
2
3
4
5
6
7
CC
Void
5G 4/1
5G 7/1
5B 7/1
5G 7/1
5B 7/1
5G 6/1
5G 4/1
5G 7/1, burrow
5G 4/1
sharp contact
5B 7/1
5G 4/1
5B 7/1
5G 4/1

LITHOLOGIC DESCRIPTION

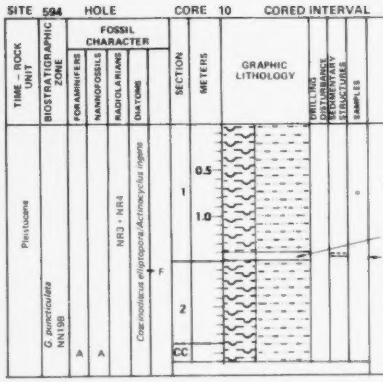
NANNOFOSSIL OOZE, light gray (5G 7/1, 5B 7/1), with subtle color cycles, somewhat bioturbated, some iron sulfide.

SPONGE SPICULE-BEARING, DIATOM-BEARING, NANNOFOSSIL-BEARING, FORAMINIFER-BEARING CLAYEY SILT, dark greenish gray (5G 4/1, 5G 6/1), homogeneous, bioturbated, H_2S strong.

SMEAR SLIDE SUMMARY

	4, 90	6, 90
	D	D
Texture		
Silt	–	C
Clay	–	D
Composition		
Quartz	C	R
Feldspar	T	–
Mica	C	R
Clay	C	–
Volcanic glass	R	–
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	C	D
Diatoms	C	T
Radiolarians	T	–
Sponge spicules	C	T

SITE 594 HOLE CORE 10 CORED INTERVAL 82.7–92.3 m



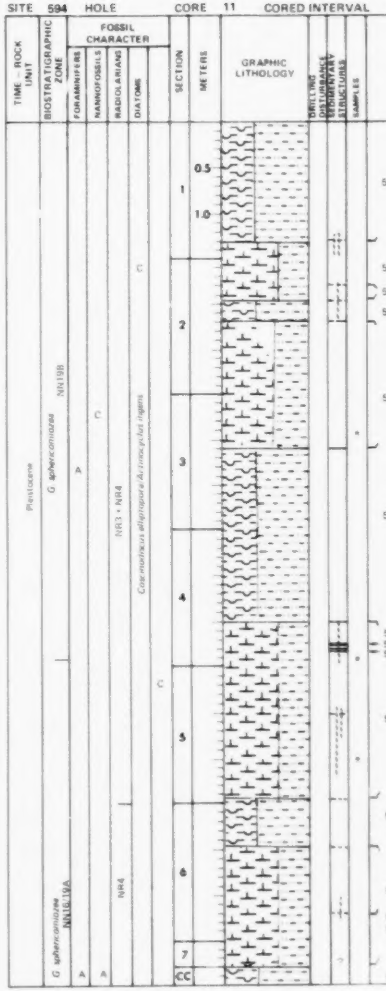
LITHOLOGIC DESCRIPTION

DIATOMACEOUS SPONGE SPICULE SILT, dark green (5G 4/1), very fine-grained, homogeneous, occasional burrows.

SMEAR SLIDE SUMMARY

	1, 70
	D
Composition	
Quartz	C
Mica	C
Pyrite	T
Foraminifers	R
Calc. nannofssils	R
Diatoms	C
Radiolarians	T
Sponge spicules	C
Unidentified	C

SITE 594 HOLE CORE 11 CORED INTERVAL 92.3–101.9 m

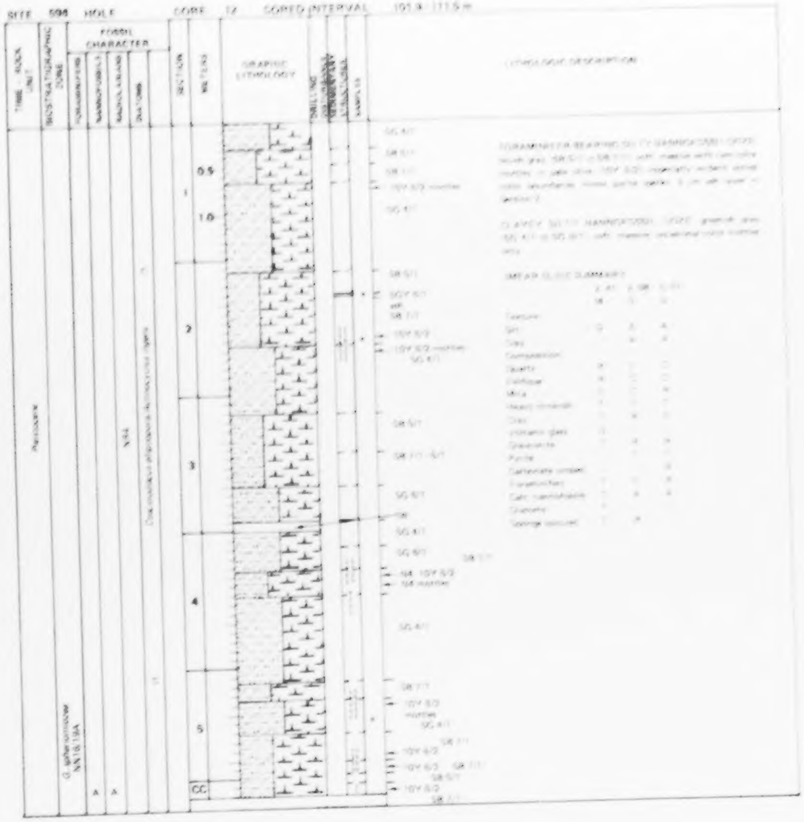


LITHOLOGIC DESCRIPTION

DIATOMACEOUS SPONGE SPICULE SILT, dark greenish gray (5G 4/1, 5G 5/1), homogeneous, minor burrowing and FORAMINIFER-BEARING SILTY NANNOFOSSIL OOZE, light bluish gray (5B 7/1, 5B 6/1), burrow mottled, common large benthic forams, disseminated pyrite.

SMEAR SLIDE SUMMARY

	3, 45	4, 142	5, 102
	D	D	D
Texture			
Silt	A	C	A
Clay	A	A	A
Composition			
Quartz	C	R	C
Feldspar	C	R	C
Mica	R	R	C
Heavy minerals	T	–	–
Clay	C	R	C
Volcanic glass	T	T	–
Glauconite	–	T	–
Pyrite	T	T	–
Carbonate unspec	T	T	–
Foraminifers	C	C	R
Calc. nannofossils	A	A	C
Diatoms	–	R	–
Radiolarians	T	T	–
Sponge spicules	R	R	–


SITE 594 HOLE CORE 12 CORED INTERVAL 101.9–111.5 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Pleistocene
NN18/19A
A
A
0.5
1.0
1
2
3
4
5
CC
5G 4/1
5B 5/1
5B 7/1
10Y 6/2 mottles
5G 6/1
5G 5/1
10Y 6/2
5B 7/1
5G 4/1

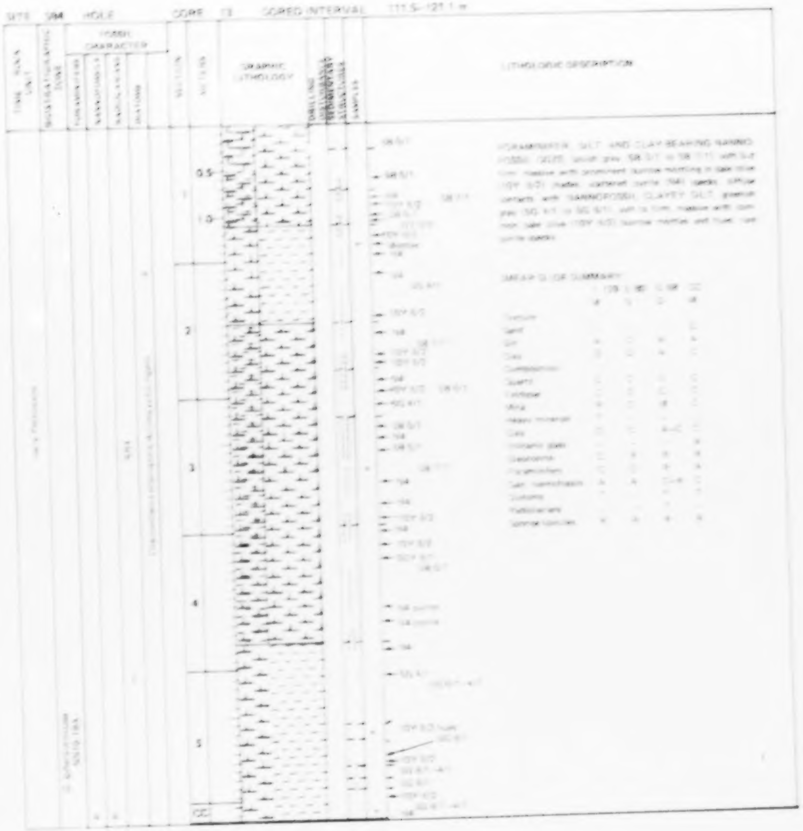
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING SILTY NANNOFOSSIL OOZE, bluish gray (5B 5/1 to 5B 7/1), with massive with [illegible] mottles in pale olive (10Y 6/2), especially evident across color boundaries. Minor pyrite specks. 3 cm ash layer in Section 2.

CLAYEY SILTY NANNOFOSSIL OOZE, greenish gray (5G 4/1 to 5G 6/1), with massive, occasional color mottling.

SMEAR SLIDE SUMMARY

	2, 41	2, 98	3, 77
	M	D	D
Texture:			
Silt	[illegible]	[illegible]	[illegible]
Clay	[illegible]	[illegible]	[illegible]
Composition:			
Quartz	[illegible]	[illegible]	[illegible]
Feldspar	[illegible]	[illegible]	[illegible]
Mica	[illegible]	[illegible]	[illegible]
Heavy minerals	[illegible]	[illegible]	[illegible]
Clay	[illegible]	[illegible]	[illegible]
Volcanic glass	[illegible]		
Glauconite	[illegible]	[illegible]	[illegible]
Pyrite		[illegible]	[illegible]
Carbonate unspec.	[illegible]		[illegible]
Foraminifers	[illegible]	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]	[illegible]
Diatoms	[illegible]		
Sponge spicules	[illegible]	[illegible]	


SITE 594 HOLE CORE 13 CORED INTERVAL 111.5–121.1 m
TIME-ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
NN18/19A
A
A
0.5
1.0
1
2
3
4
5
CC
5B 5/1
10Y 6/2
5G 4/1
5B 7/1
5G 6/1

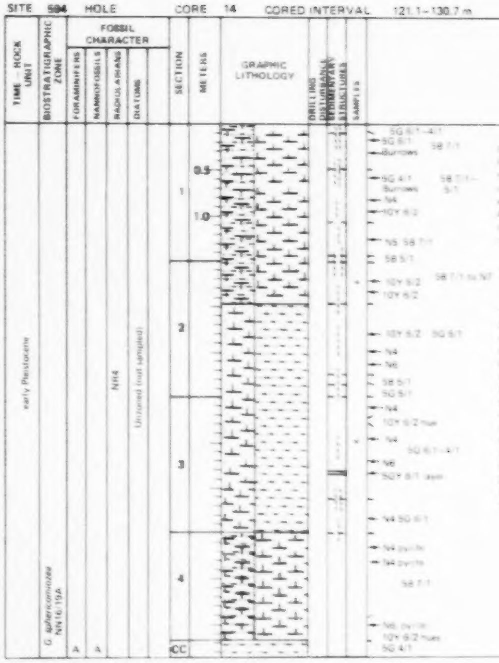
LITHOLOGIC DESCRIPTION

FORAMINIFER-, SILT- AND CLAY-BEARING NANNOFOSSIL OOZE, bluish gray (5B 5/1 to 5B 7/1), soft to firm, massive with prominent burrow mottling in pale olive (10Y 6/2) shades, scattered pyrite (M4) specks. Diffuse contacts with NANNOFOSSIL CLAYEY SILT, greenish gray (5G 4/1 to 5G 6/1), soft to firm, massive with common pale olive (10Y 6/2) burrow mottles and fewer rare pyrite specks.

SMEAR SLIDE SUMMARY

	1, 129	2, 80	3, 98	CC
	M	D	D	M
Texture:				
Sand				[illegible]
Silt	[illegible]	[illegible]	[illegible]	[illegible]
Clay	[illegible]	[illegible]	[illegible]	[illegible]
Composition:				
Quartz	[illegible]	[illegible]	[illegible]	[illegible]
Feldspar	[illegible]	[illegible]	[illegible]	[illegible]
Mica	[illegible]	[illegible]	[illegible]	[illegible]
Heavy minerals	[illegible]	[illegible]	[illegible]	
Clay	[illegible]	[illegible]	[illegible]	[illegible]
Volcanic glass	[illegible]	[illegible]	[illegible]	[illegible]
Glauconite	[illegible]	[illegible]	[illegible]	[illegible]
Foraminifers	[illegible]	[illegible]	[illegible]	[illegible]
Calc. nannofossils	[illegible]	[illegible]	[illegible]	[illegible]
Diatoms	[illegible]		[illegible]	[illegible]
Radiolarians	[illegible]	[illegible]	[illegible]	[illegible]
Sponge spicules	[illegible]	[illegible]	[illegible]	[illegible]

SITE 594 HOLE CORE 14 CORED INTERVAL 121.1–130.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
G. sphericomiozea NN16/19A
A
A
NH4
Unzoned (not sampled)
0.5
1.0
1
2
3
4
CC
5G 6/1–4/1
5G 6/1
5B 7/1
Burrows
5G 4/1
5B 7/1–5/1
Burrows
N4
10Y 6/2
N5 5B 7/1
5B 5/1
10Y 6/2
5B 7/1 to N7
10Y 6/2
10Y 6/2
5G 6/1
N4
N6
5B 5/1
5G 6/1
N4
10Y 6/2 hue
N4
5G 6/1–4/1
N6
5GY 6/1 layer
N4 5G 6/1
N4 pyrite
N4 pyrite
5B 7/1
N6 pyrite
10Y 6/2 hues
5G 4/1

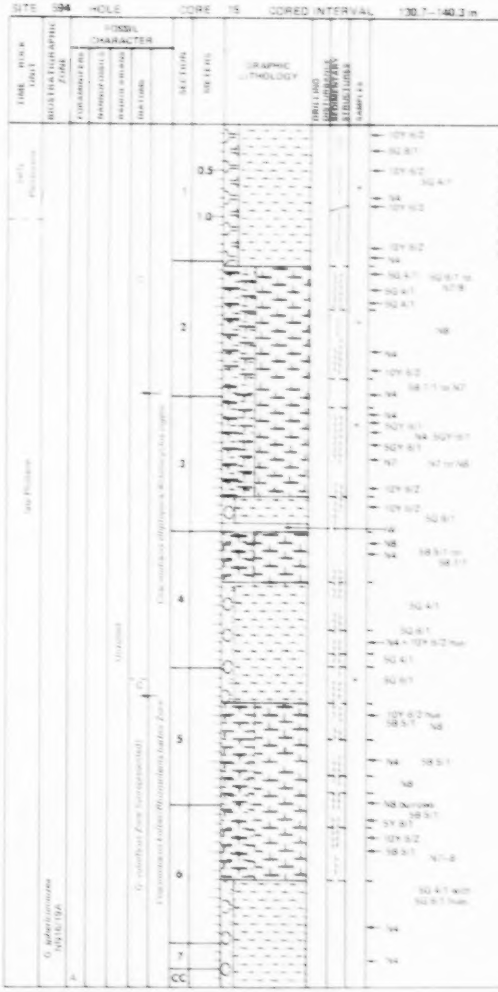
LITHOLOGIC DESCRIPTION

FORAMINIFER-, CLAY-, AND SILT-BEARING NANNOFOSSIL OOZE, bluish gray (5B 6/1 to 5B 7/1), soft to firm, massive with extensive pale olive (10Y 6/2) and other color burrow mottling, scattered pyrite specks, alternating with NANNOFOSSIL CLAYEY SILT, greenish gray (5G 4/1 to 5G 6/1) with much local color variation due principally to burrow mottles, with pale olive (10Y 6/2) hues, rare pyrite (N4 to N6).

SMEAR SLIDE SUMMARY

	2, 01	3, 94
	D	D
Texture:		
Silt	A	A
Clay	D	D
Composition:		
Quartz	C	C
Feldspar	R	C
Mica	T	R
Heavy minerals	T	T
Clay	C	C
Glauconite	T	T
Pyrite	—	T
Foraminifers	C	R
Calc. nannofossils	D	A
Diatoms	T	T
Radiolarians	T	T
Sponge spicules	A	R

SITE 594 HOLE CORE 15 CORED INTERVAL 130.7–140.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
late Pliocene
G. sphericomiozea NN16/19A
A
Unzoned
0.5
1.0
1
2
3
4
5
6
7
CC
10Y 6/2
5G 6/1
10Y 6/2
5G 4/1
N4
10Y 6/2
10Y 6/2
N4
5G 4/1
5G 6/1
5G 4/1
N8
N4
10Y 6/2
5B 7/1 to N7
N4
5GY 6/1
N7
N7 to N6
10Y 6/2
10Y 6/2
5G 6/1
N8
N4
5B 5/1 to 5B 7/1
5G 4/1
5G 6/1
N4 + 10Y 6/2 hue
5G 4/1
5G 6/1
10Y 6/2 hue
5B 5/1
N8
N4
5B 5/1
N8
N8 burrows
5B 5/1
5Y 6/1
10Y 6/2
5B 5/1
N7–8
5G 4/1 with 5G 6/1 hues
N4
N4

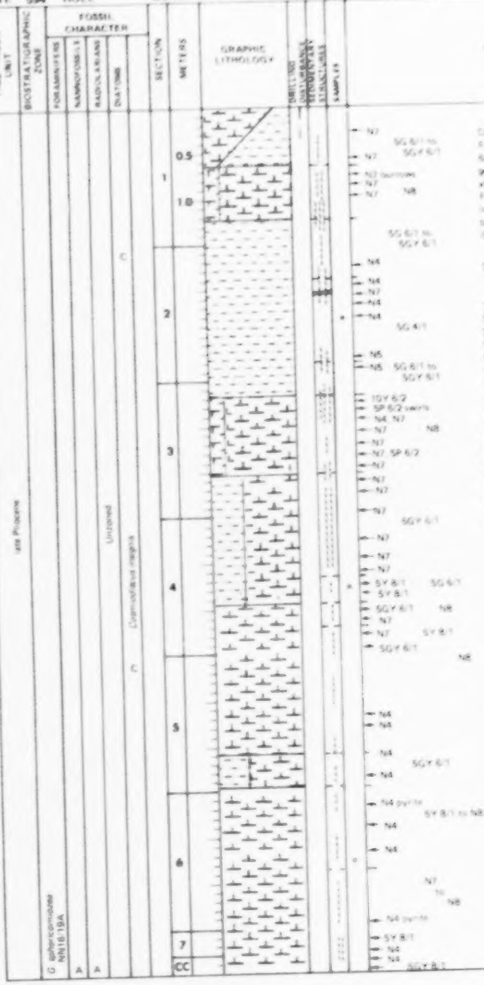
LITHOLOGIC DESCRIPTION

FORAMINIFER-, SILT-, AND CLAY-BEARING NANNOFOSSIL OOZE, bluish gray (5B 7/1 to 5B 5/1) to very light or light gray (N8 or N7), stiff, massive with color mottling and hues in pale olive (10Y 6/2) tones, extensive burrowing especially evident across color boundaries, scattered pyrite (N4), alternating with SPONGE SPICULE-BEARING CLAYEY SILT, greenish gray (5G 4/1 to 5G 6/1), stiff, massive with hues and burrow mottling of pale olive (10Y 6/2) color, scattered pyrite (N4).

SMEAR SLIDE SUMMARY

	1, 70	2, 70	3, 28	6, 18
	D	D	M	M
Texture:				
Sand	—	—	R	R
Silt	A	C	C	C
Clay	A	D	D	D
Composition:				
Quartz	C	C	C	R
Feldspar	C	R	C	C
Mica	C	T	R	—
Heavy minerals	T	T	T	—
Clay	A	C	C	C
Volcanic glass	T	—	—	—
Glauconite	T	T	—	—
Pyrite	T	—	R	R
Foraminifers	T	C	C	C
Calc. nannofossils	R	D	A	A
Diatoms	—	—	T	—
Radiolarians	—	—	T	—
Sponge spicules	C	R	R	R

SITE 594 HOLE CORE 16 CORED INTERVAL 140.3–149.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Pliocene
G. sphaeroidalis
NN16/19A
A
A
Unzoned
C
C
Coscinodiscus marginatus
0.5
1.0
1
2
3
4
5
6
7
CC
N7
5G 6/1 to 5GY 6/1
N7 burrows
N8
N4
5G 4/1
N5
10Y 6/2
5P 6/2 swirls
N7
5P 6/2
5GY 6/1
5Y 8/1
5G 6/1
N4 pyrite
5Y 8/1 to N8
N7 to N8
N4 pyrite
5GY 8/1

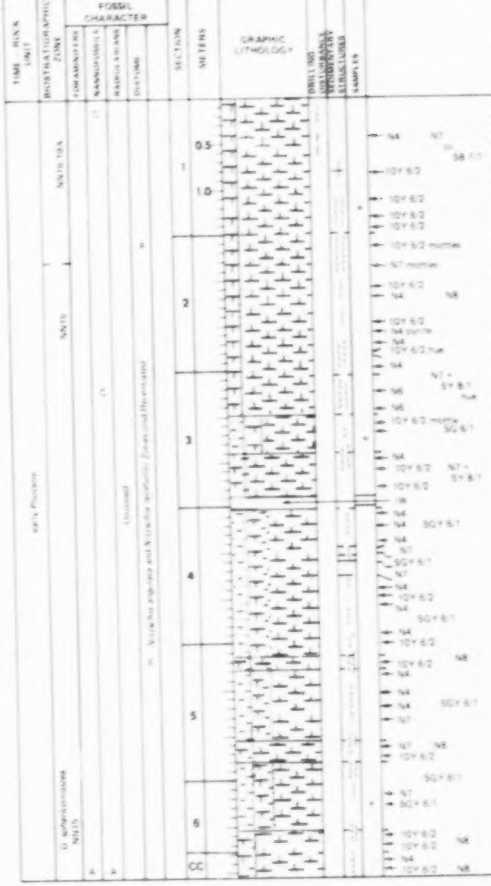
CLAYEY SILT TO CLAY, AND SILT BEARING NANNOFOSSIL OOZE, greenish gray (5G 4/1, 5G 6/1 and 5GY 6/1), stiff, massive but burrow mottling pervasive in light grays (N7) and other colors, scattered pyrite specks (N4/5), alternating with (FORAMINIFER BEARING) NANNOFOSSIL OOZE, light or very light gray (N7 or N8) to yellowish gray (5Y 8/1), stiff, massive but intensely bioturbated and burrow mottled in light grays (N7), pale purples (5P 6/2) and pale olives (10Y 6/2), rare pyrite (N4) specks.

SMEAR SLIDE SUMMARY

	2, 80	4, 80	6, 80
	D	D	D
Texture:			
Sand	R	–	–
Silt	A	R	C
Clay	A	D	D
Composition:			
Quartz	C	R	R
Feldspar	C	R	R
Mica	C	T	R
Heavy minerals	T	–	T
Clay	C	T	R
Volcanic glass	T	–	–
Glauconite	T	–	–
Pyrite	T	T	T
Foraminifers	T	R	R
Calc. nannofossils	T	D	D
Diatoms	–	T	–
Radiolarians	T	T	–
Sponge spicules	R	R	R

Core 17 – no recovery

SITE 594 HOLE CORE 18 CORED INTERVAL 159.5–169.1 m

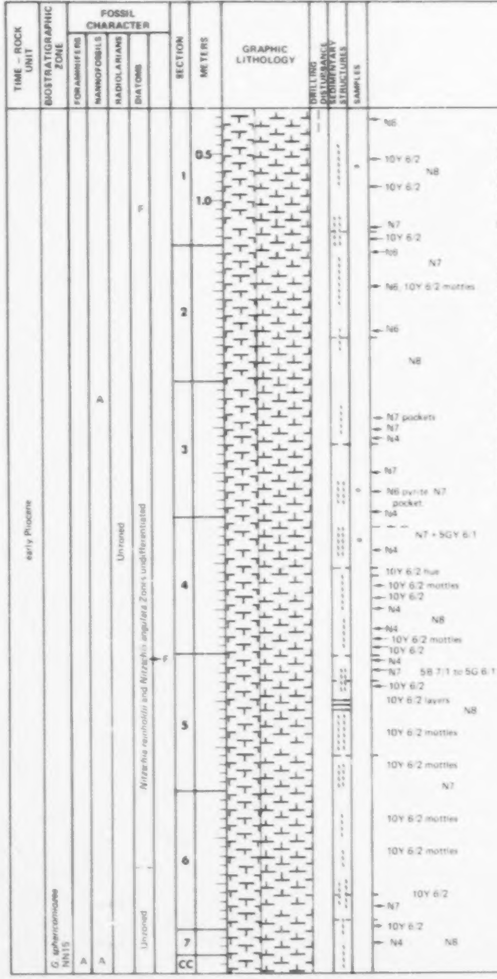

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
NN16/19A
NN15
G. sphaeroidalis
NN15
A
A
C
C
R
Unzoned
0.5
1.0
1
2
3
4
5
6
CC
N4
N7 to 5B 7/1
10Y 6/2
10Y 6/2 mottles
N7 mottles
N8
N4 pyrite
10Y 6/2 hue
N7 + 5Y 8/1 hue
10Y 6/2 mottle
5G 6/1
5GY 6/1
N7
5GY 8/1

NANNOFOSSIL OOZE TO FORAMINIFER BEARING NANNOFOSSIL OOZE, very light to light gray (N8 to N7), sometimes with light bluish gray (5B 7/1) or yellowish gray (5Y 8/1) hues, stiff, massive but extensively burrow mottled in pale olive (10Y 6/2) and gray (N7) tones, small sandy pockets throughout, scattered pyrite (N4), alternating with FORAMINIFER, SILT AND/OR CLAY BEARING NANNOFOSSIL OOZE, greenish gray (5G 6/1 to 5GY 6/1), stiff, silty feel, prominently burrow mottled in pale olive (10Y 6/2) and other hues, common pyrite (N4).

SMEAR SLIDE SUMMARY

	1, 124	3, 80	5, 125
	D	D	D
Texture:			
Sand	–	–	R
Silt	R	A	C
Clay	D	A	D
Composition:			
Quartz	R	C	R
Feldspar	T	R	R
Mica	T	R	R
Heavy minerals	T	–	T
Clay	R	C	C
Volcanic glass	–	T	T
Glauconite	T	T	R
Pyrite	T	T	T
Foraminifers	R	C	C
Calc. nannofossils	D	C	A
Diatoms	T	–	–
Radiolarians	T	–	T
Sponge spicules	R	R	R

SITE 594 HOLE CORE 19 CORED INTERVAL 169.1–178.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. sphericomiozea
NN15
A
A
Unzoned
Nitzschia reinholdii and Nitzschia angulata Zones undifferentiated
Unzoned
F
F
0.5
1.0
1
2
3
4
5
6
7
CC
N6
10Y 6/2
N8
10Y 6/2
N7
10Y 6/2
N6
N7
N6, 10Y 6/2 mottles
N6
N8
N7 pockets
N7
N4
N7
N6 pyrite N7 pocket
N4
N7 + 5GY 6/1
N4
10Y 6/2 hue
10Y 6/2 mottles
10Y 6/2
N4
N8
N4
10Y 6/2 mottles
10Y 6/2
N4
N7
5B 7/1 to 5G 6/1
10Y 6/2
10Y 6/2 layers
N8
10Y 6/2 mottles
10Y 6/2 mottles
N7
10Y 6/2 mottles
10Y 6/2 mottles
10Y 6/2
N7
10Y 6/2
N4
N8

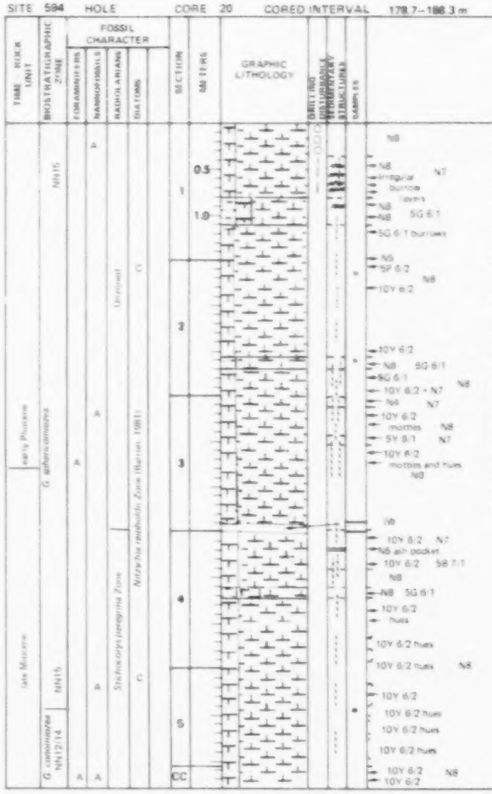
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light to light gray (N8 to N7) with common pale olive (10Y 6/2) or yellowish gray (5GY 8/1) tones superimposed, burrow mottled in similar colors, stiff, massive, prominent burrow structures, scattered pyrite (N4 to N6), occasional hard layers.

SMEAR SLIDE SUMMARY

	1, 70	3, 129	4, 26
	D	M	D
Texture:			
Sand	–	A	–
Silt	C	C	C
Clay	D	C	A
Composition:			
Quartz	T	T	R
Feldspar	–	T	R
Mica	T	T	R
Heavy minerals	T	–	T
Clay	–	–	R
Volcanic glass	–	T	–
Glauconite	–	–	T+
Pyrite	T	R	–
Foraminifers	C	C	C
Calc. nannofossils	D	A	A
Radiolarians	T	T	T
Sponge spicules	R	R	R
Microtektite	–	T	–

SITE 594 HOLE CORE 20 CORED INTERVAL 178.7–188.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
late Miocene
NN15
G. sphericomiozea
NN15
G. conomiozea
NN12/14
A
A
A
A
A
A
A
Unzoned
Stichocorys peregrina Zone
C
Nitzschia reinholdii Zone (Barron, 1981)
C
0.5
1.0
1
2
3
4
5
CC
N8
N8
irregular burrow layers
N7
N8
N8
5G 6/1
5G 6/1 burrows
N6
5P 6/2
N8
10Y 6/2
10Y 6/2
N8
5G 6/1
5G 6/1
10Y 6/2 + N7
N8
N4
N7
10Y 6/2 mottles
N8
5Y 8/1
N7
10Y 6/2 mottles and hues
N8
N8
10Y 6/2
N7
N8 ash pocket
10Y 6/2
5B 7/1
N8
N8
5G 6/1
10Y 6/2 hues
10Y 6/2 hues
10Y 6/2 hues
N8
10Y 6/2
10Y 6/2 hues
10Y 6/2 hues
10Y 6/2 hues
10Y 6/2
N8
10Y 6/2

LITHOLOGIC DESCRIPTION

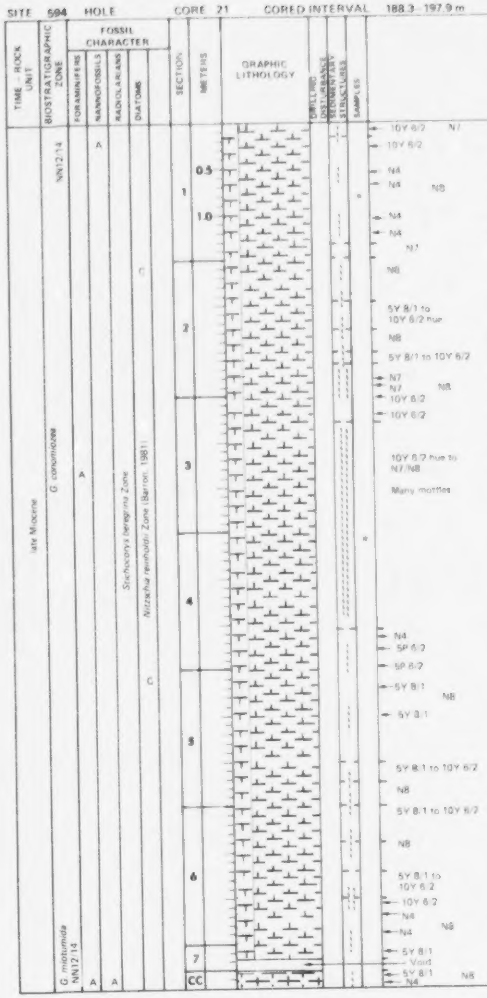
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light to light gray (N8 to N7) or bluish gray (5B 7/1) with subtle superimposed shades of pale olive (10Y 6/2) at several levels (these may be clay bearing), stiff with hard layers occasionally, strongly burrow mottled.

CLAY-, SILT-, AND FORAMINIFER-BEARING NANNOFOSSIL OOZE, greenish gray (5G 6/1) with similar characteristics to FORAMINIFER-BEARING NANNOFOSSIL OOZE.

SMEAR SLIDE SUMMARY

	2, 24	2, 114	5, 48
	D	D	D
Texture:			
Silt	C	–	C
Clay	D	–	D
Composition:			
Quartz	R	C	R
Feldspar	–	T	–
Mica	–	T	R
Clay	–	C	C
Volcanic glass	–	T	–
Glauconite	–	R	T
Pyrite	T	T	T
Foraminifers	C	C	C
Calc. nannofossils	D	A	A
Radiolarians	–	–	T
Sponge spicules	R	R	R

SITE 594 HOLE CORE 21 CORED INTERVAL 188.3–197.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN12/14
G. conomiozea
G. miotumida
NN12/14
A
A
C
C
A
A
Stichocorys peregrina Zone
Nitzschia reinholdii Zone (Barron, 1981)
0.5
1.0
1
2
3
4
5
6
7
CC
10Y 6/2
N7
10Y 6/2
N4
N4
N8
N4
N4
N7
N8
5Y 8/1 to 10Y 6/2 hue
N8
5Y 8/1 to 10Y 6/2
N7
N7
N8
10Y 6/2
10Y 6/2
10Y 6/2 hue to N7/N8
Many mottles
N4
5P 6/2
5P 6/2
5Y 8/1
N8
5Y 8/1
5Y 8/1 to 10Y 6/2
N8
5Y 8/1 to 10Y 6/2
N8
5Y 8/1 to 10Y 6/2
10Y 6/2
N4
N4
N8
5Y 8/1
Void
5Y 8/1
N8
N4

LITHOLOGIC DESCRIPTION

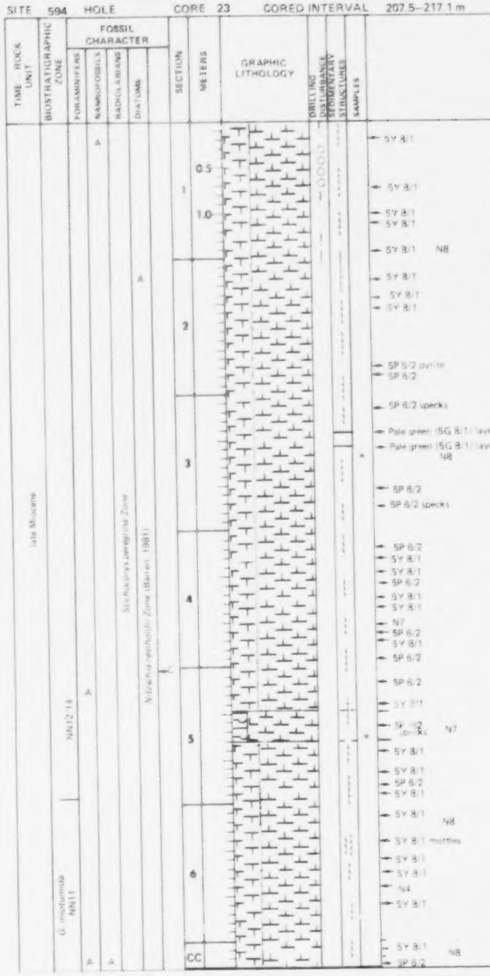
FORAMINIFER-BEARING NANNOFOSSIL OOZE TO NANNOFOSSIL OOZE, light to very light gray (N7 to N8) with yellowish gray (5Y 8/1) to pale olive (10Y 6/2) mottles and hues which become sufficiently uniform to form discrete interbeds (which are enriched in foraminifers, contain more biogenic silica, and more silt and sand sized material), stiff with occasional hard layers, profusely burrow mottled and scattered pyritized specks (N4).

SMEAR SLIDE SUMMARY

	1, 80	4, 15
	D	D
Texture:		
Sand	–	R
Silt	R	C
Clay	D	A
Composition:		
Quartz	T	T
Feldspar	T	T
Glauconite	–	T
Pyrite	T	T
Foraminifers	R	C
Calc. nannofossils	D	A
Radiolarians	T	R
Sponge spicules	R	T+
Silicoflagellates	–	R

Core 22 — no recovery

SITE 594 HOLE CORE 23 CORED INTERVAL 207.5–217.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN12/14
G. miotumida
NN11
A
A
A
C
A
A
Stichocorys peregrina Zone
Nitzschia reinholdii Zone (Barron, 1981)
0.5
1.0
1
2
3
4
5
6
CC
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
N8
5Y 8/1
5Y 8/1
5Y 8/1
5P 6/2 pyrite
5P 6/2
5P 6/2 specks
Pale green (5G 8/1) layer
Pale green (5G 8/1) layer
N8
5P 6/2
5P 6/2 specks
5P 6/2
5Y 8/1
5Y 8/1
5P 6/2
5Y 8/1
5Y 8/1
N7
5P 6/2
5Y 8/1
5P 6/2
5P 6/2
5Y 8/1
5P 6/2 specks
N7
5Y 8/1
5Y 8/1
5P 6/2
5Y 8/1
5Y 8/1
N8
5Y 8/1 mottles
5Y 8/1
5Y 8/1
N4
5Y 8/1
5Y 8/1
N8
5P 6/2

LITHOLOGIC DESCRIPTION

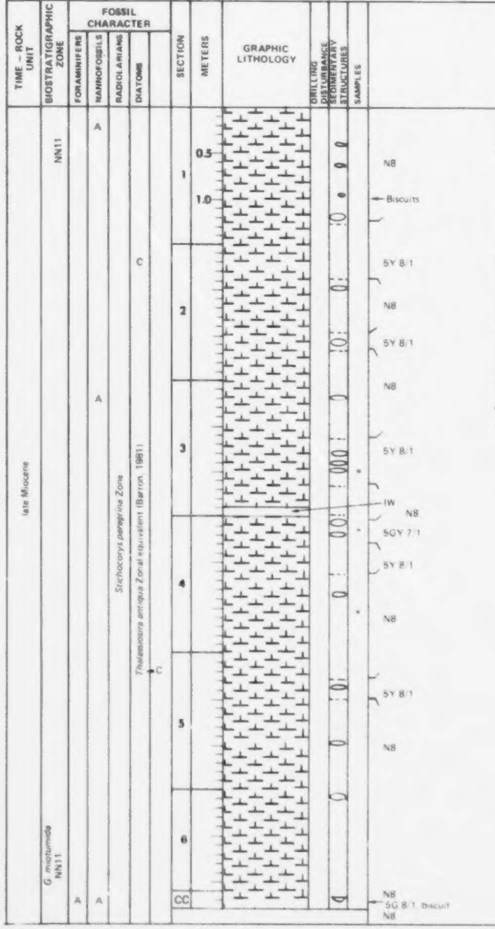
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with occasional yellowish gray (5Y 8/1) mottles and rare pyritized pale purple (5P 6/2) streaks, soft to firm with some hard layers, pale green (5G 8/1) layers in Section 3.

DIATOM-BEARING NANNOFOSSIL OOZE, light gray (N7), with similar characteristics as FORAMINIFER-BEARING NANNOFOSSIL OOZE.

SMEAR SLIDE SUMMARY

	3, 74	5, 78
	D	M
Texture:		
Silt	C	C
Clay	D	D
Composition:		
Quartz	R	–
Feldspar	T	–
Mica	T	T
Volcanic glass	–	T
Glauconite	T+	T
Pyrite	T	–
Foraminifers	C	R
Calc. nannofossils	D	D
Diatoms	T	C
Radiolarians	T+	T
Sponge spicules	R	R

SITE 594 HOLE CORE 24 CORED INTERVAL 217.1–226.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
G. miotumida NN11
A
A
C
C
Stichocorys peregrina Zone
Thalassiosira antiqua Zonal equivalent (Barron, 1981)
0.5
1.0
1
2
3
4
5
6
CC
N8
Biscuits
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
IW
N8
5GY 7/1
5Y 8/1
N8
5Y 8/1
N8
N8
5G 8/1 biscuit
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE very light gray (N8), soft, with occasional biscuits of harder chalk, pyrite specks. Some interbeds of DIATOM-BEARING NANNOFOSSIL OOZE grayish yellow (5Y 8/1), streaks of pyrite.

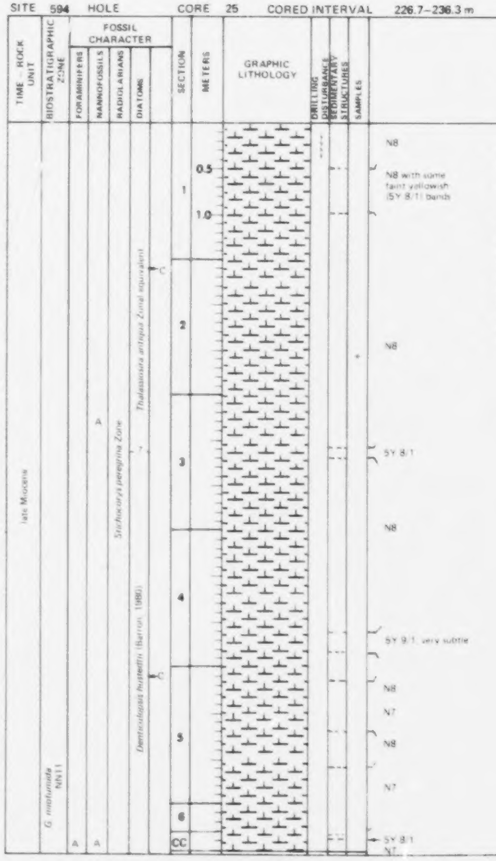
SMEAR SLIDE SUMMARY

	3, 99	4, 16	4, 105
	D	M	D
Texture			
Silt	A	–	C
Clay	A	–	D
Composition			
Quartz	T	T	–
Mica	T	T	T
Pyrite	–	T	–
Foraminifers	R	C	R
Calc. nannofossils	D	A	D
Diatoms	C	C	R
Radiolarians	T	T	T
Sponge spicules	T	R	R

⬭ = Biscuit

– – – = Gradational contact

SITE 594 HOLE CORE 25 CORED INTERVAL 226.7–236.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida NN11
A
A
A
C
C
Stichocorys peregrina Zone
Thalassiosira antiqua Zonal equivalent
?
Denticulopsis hustedtii (Barron, 1980)
0.5
1.0
1
2
3
4
5
6
CC
N8
N8 with some faint yellowish (5Y 8/1) bands
N8
5Y 8/1
N8
5Y 8/1 very subtle
N8
N7
N8
N7
5Y 8/1
N7

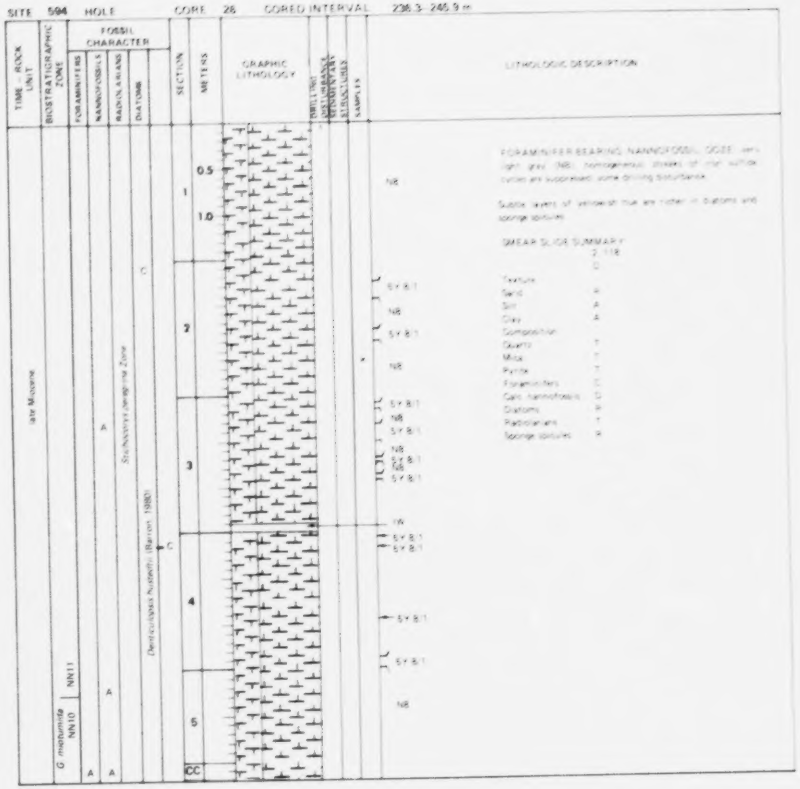
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft almost homogeneous, some pyrite, cycles are not obvious.

SMEAR SLIDE SUMMARY

	2, 110
	D
Texture	
Silt	A
Clay	A
Composition	
Mica	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	R
Radiolarians	T
Sponge spicules	R

SITE 594 HOLE CORE 26 CORED INTERVAL 236.3–245.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN10
NN11
A
A
A
A
Stichocorys peregrina Zone
Denticulopsis hustedtii (Barron, 1980)
C
C
C
1
2
3
4
5
CC
0.5
1.0
N8
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
IW
5Y 8/1
5Y 8/1
5Y 8/1
5Y 8/1
N8

LITHOLOGIC DESCRIPTION

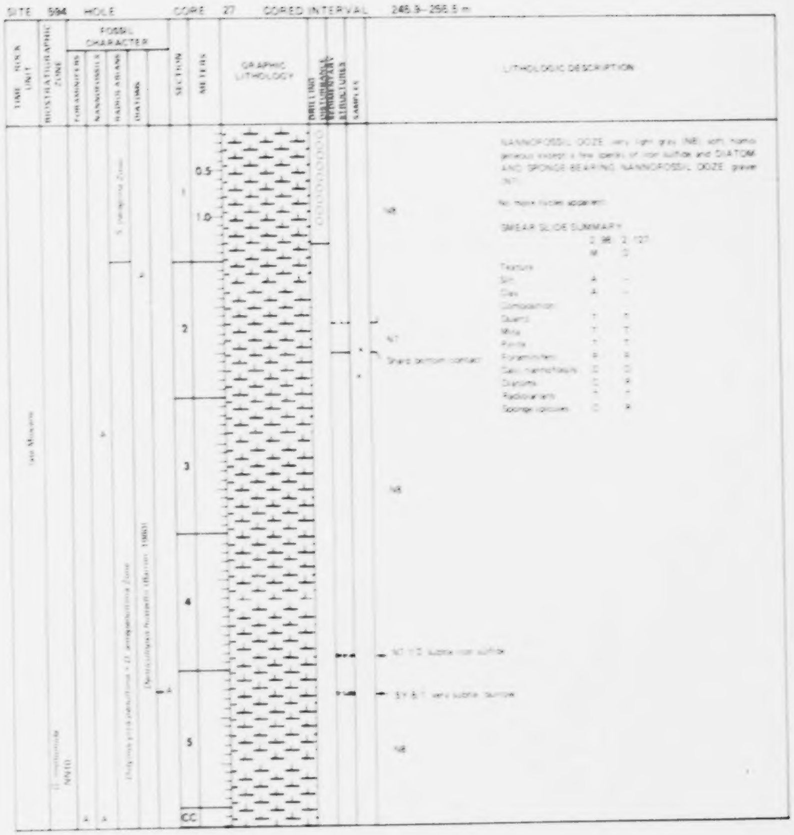
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), homogeneous; streaks of iron sulfide cycles are suppressed; some drilling disturbance.

Subtle layers of yellowish hue are richer in diatoms and sponge spicules.

SMEAR SLIDE SUMMARY

	2, 118
	D
Texture	
Sand	R
Silt	A
Clay	A
Composition	
Quartz	T
Mica	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D
Diatoms	R
Radiolarians	T
Sponge spicules	R

SITE 594 HOLE CORE 27 CORED INTERVAL 245.9–255.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida
NN10
A
A
A
S. peregrina Zone
Didymocyrtis penultima + D. antepenultima Zone
A
Denticulopsis hustedtii (Barron, 1980)
A
1
2
3
4
5
CC
0.5
1.0
N8
N7
Sharp bottom contact
N8
N7 1/2 subtle iron sulfide
5Y 8/1 very subtle burrow
N8

LITHOLOGIC DESCRIPTION

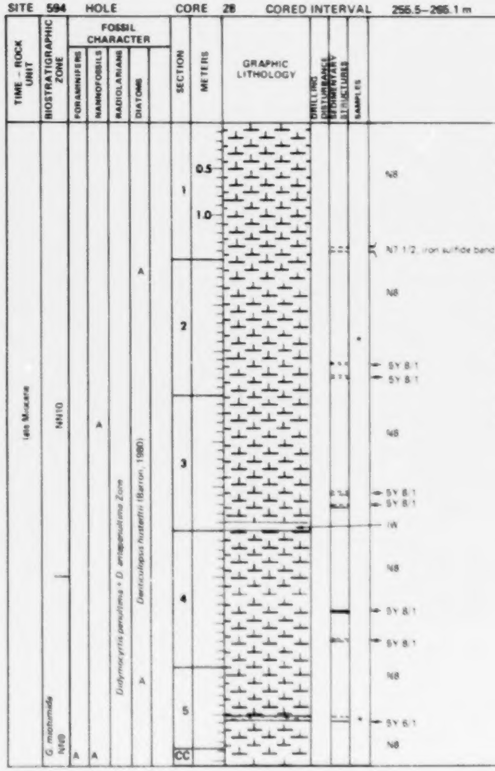
NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous except a few specks of iron sulfide and DIATOM AND SPONGE BEARING NANNOFOSSIL OOZE, grayer (N7).

No major cycles apparent.

SMEAR SLIDE SUMMARY

	2, 98	2, 127
	M	D
Texture		
Silt	A	–
Clay	A	–
Composition		
Quartz	T	T
Mica	T	T
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	C	R
Radiolarians	T	T
Sponge spicules	C	R

SITE 594 HOLE CORE 28 CORED INTERVAL 256.5–265.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN10
G. mioturnida NN9
A
A
A
A
A
Didymocyrtis penultima + D. antepenultima Zone
Denticulopsis hustedtii (Barron, 1980)
0.5
1.0
1
2
3
4
5
CC
N8
N7 1/2, iron sulfide band
N8
5Y 8/1
5Y 8/1
N8
5Y 8/1
5Y 8/1
IW
N8
5Y 8/1
5Y 8/1
N8
5Y 6/1
N8

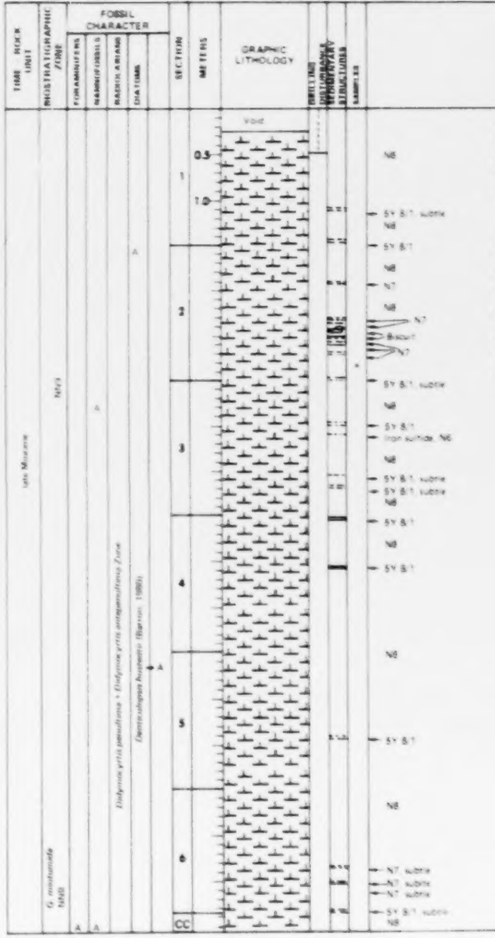
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firmer, pyrite stains throughout, subtle light grayish yellow (5Y 8/1) burrows and VOLCANIC ASH, light olive gray (5Y 6/1), minor lithology at Section 5, 56–57 cm, sharp bottom contact and gradational upper contact.

SMEAR SLIDE SUMMARY

	2, 80	5, 56
	D	M
Texture		
Sand	–	R
Silt	C	A
Clay	D	A
Composition		
Quartz	T	T
Mica	–	T
Volcanic glass	–	A
Pyrite	–	R
Foraminifers	R	R
Calc. nannofossils	D	A
Diatoms	R	R
Radiolarians	T	T
Sponge spicules	R	R

SITE 594 HOLE CORE 29 CORED INTERVAL 265.1–274.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN11
G. mioturnida NN8
A
A
A
A
A
Didymocyrtis penultima + Didymocyrtis antepenultima Zone
Denticulopsis hustedtii (Barron, 1980)
Void
0.5
1.0
1
2
3
4
5
6
CC
N8
5Y 8/1, subtle
N8
5Y 8/1
N8
N7
N8
N7
Biscuit
N7
5Y 8/1, subtle
N8
5Y 8/1
iron sulfide, N6
N8
5Y 8/1, subtle
5Y 8/1, subtle
N8
5Y 8/1
N8
5Y 8/1
N8
5Y 8/1
N8
N7, subtle
N7, subtle
N7, subtle
5Y 8/1, subtle
N8

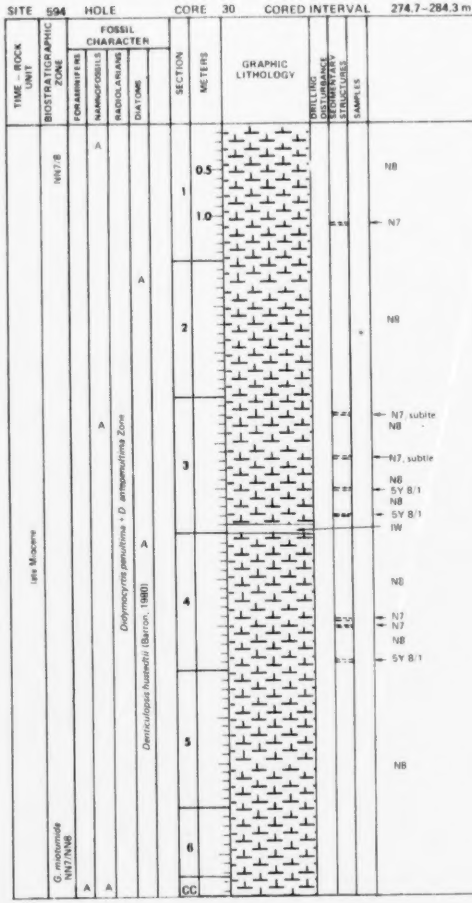
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), with specks of iron sulfide of light gray (N7), with biscuits of firmer ooze and SPONGE SPICULE- AND DIATOM-BEARING NANNOFOSSIL OOZE, light yellowish gray bands (5Y 8/1).

SMEAR SLIDE SUMMARY

	2, 132	2, 145
	D	M
Texture		
Silt	A	–
Clay	A	–
Composition		
Quartz	T	T
Mica	T	T
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	C	C
Radiolarians	T	T
Sponge spicules	C	C

SITE 594 HOLE CORE 30 CORED INTERVAL 274.7–284.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
NN7/8
G. miotumida NN7/NN8
A
A
A
A
A
A
A
Didymocyrtis penultima + D. antepenultima Zone
Denticulopsis hustedtii (Barron, 1980)
1
2
3
4
5
6
CC
0.5
1.0
N8
N7
N8
N7, subite
N8
N7, subtle
N8
5Y 8/1
N8
5Y 8/1
IW
N8
N7
N7
N8
5Y 8/1
N8

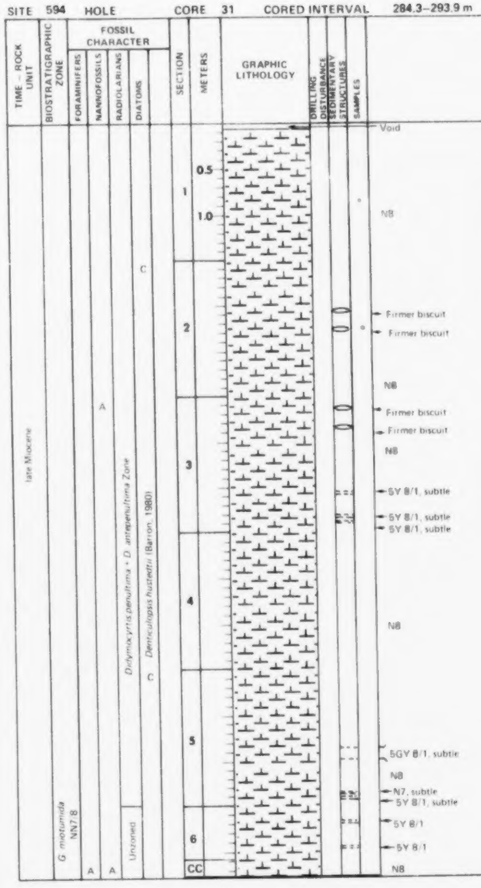
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), with specks of iron sulfide (N7), homogeneous except for variations of firmer and less firm ooze.

SMEAR SLIDE SUMMARY

	2, 80
	D
Texture:	
Silt	C
Clay	D
Composition:	
Quartz	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	R
Radiolarians	T
Sponge spicules	R

SITE 594 HOLE CORE 31 CORED INTERVAL 284.3–293.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida NN7/8
A
A
A
C
C
Didymocyrtis penultima + D. antepenultima Zone
Unzoned
Denticulopsis hustedtii (Barron, 1980)
1
2
3
4
5
6
CC
0.5
1.0
Void
N8
Firmer biscuit
Firmer biscuit
N8
Firmer biscuit
Firmer biscuit
N8
5Y 8/1, subtle
5Y 8/1, subtle
5Y 8/1, subtle
N8
5GY 8/1, subtle
N8
N7, subtle
5Y 8/1, subtle
5Y 8/1
5Y 8/1
N8

LITHOLOGIC DESCRIPTION

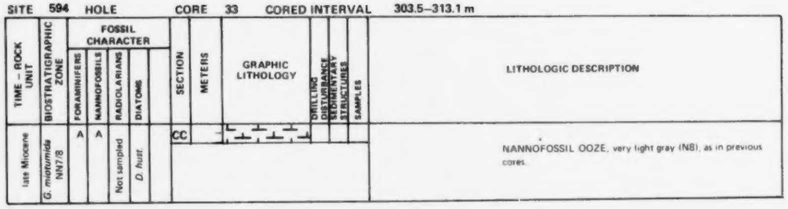
NANNOFOSSIL OOZE, very light gray (N8), homogeneous except a few specks of iron sulfide, a few biscuits of firmer ooze, and a few silica-rich(?) yellowish bands.

SMEAR SLIDE SUMMARY

	1, 84	2, 80
	D	D
Composition:		
Quartz	T	T
Mica	T	T
Volcanic glass	T	–
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D
Diatoms	T	T
Radiolarians	–	T
Sponge spicules	R	R

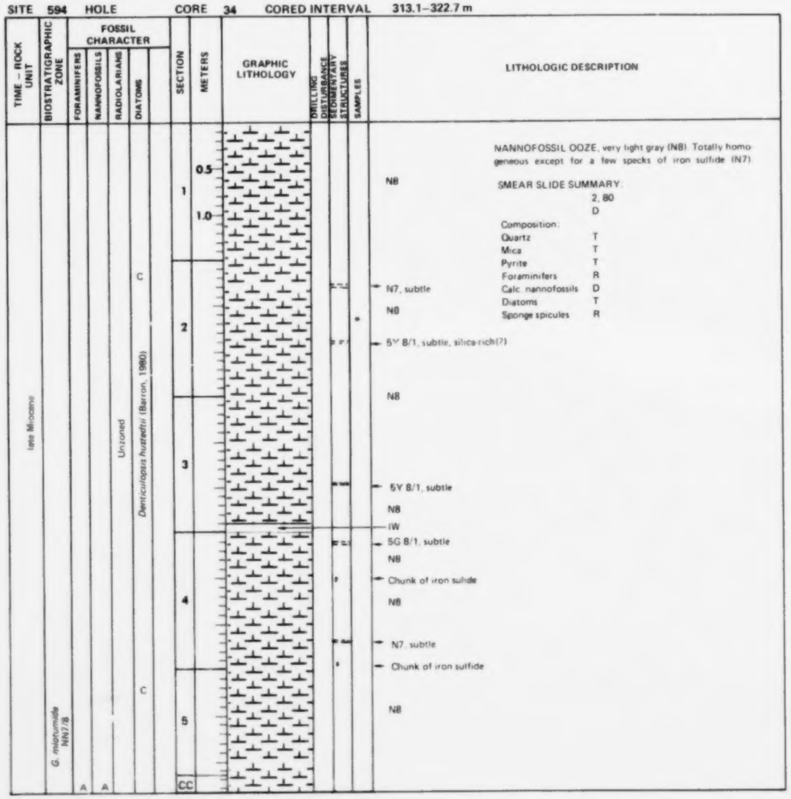
NOTE: Core 32, 293.9–303.5 m: no recovery

SITE 594 HOLE CORE 33 CORED INTERVAL 303.5–313.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. miotumida NN7/8
A
A
Not sampled
D. hust
CC

NANNOFOSSIL OOZE, very light gray (N8), as in previous cores.

SITE 594 HOLE CORE 34 CORED INTERVAL 313.1–322.7 m

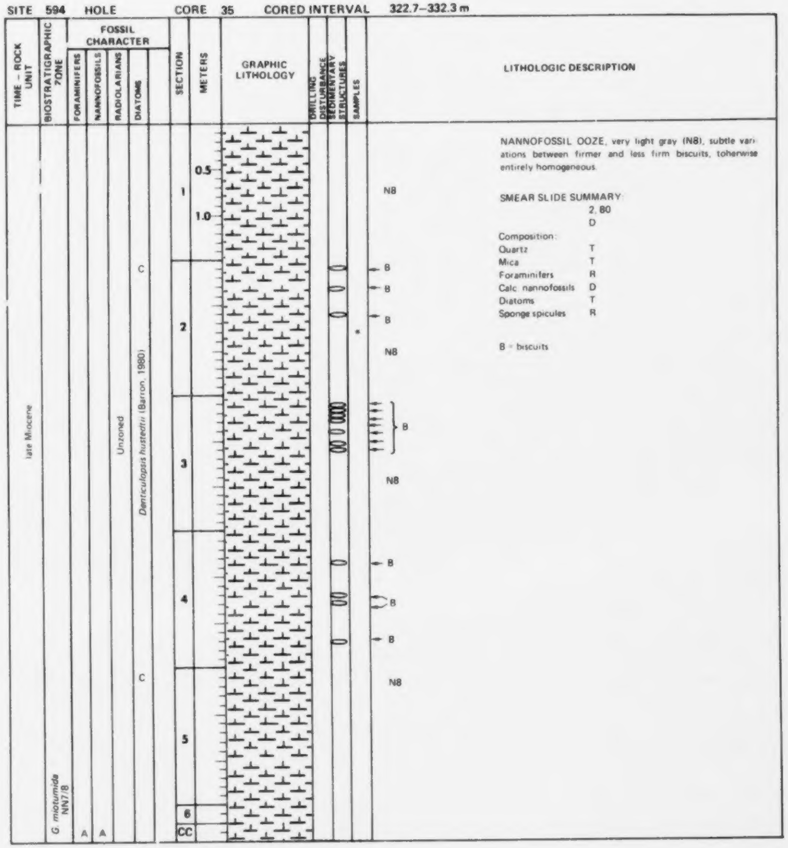

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. miotumida NN7/8
A
A
Unzoned
Denticulopsis hustedtii (Barron, 1980)
C
C
1
2
3
4
5
CC
0.5
1.0
N8
N7, subtle
N8
5Y 8/1, subtle, silica-rich(?)
N8
5Y 8/1, subtle
N8
IW
5G 8/1, subtle
N8
Chunk of iron sulfide
N8
N7, subtle
Chunk of iron sulfide
N8

NANNOFOSSIL OOZE, very light gray (N8). Totally homogeneous except for a few specks of iron sulfide (N7).

SMEAR SLIDE SUMMARY:

	2, 80
	D
Composition:	
Quartz	T
Mica	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

SITE 594 HOLE CORE 35 CORED INTERVAL 322.7–332.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. miotumida NN7/8
A
A
Unzoned
Denticulopsis hustedtii (Barron, 1980)
C
C
1
2
3
4
5
6
CC
0.5
1.0
N8
B
B
B
N8
B
N8
B
B
B
N8

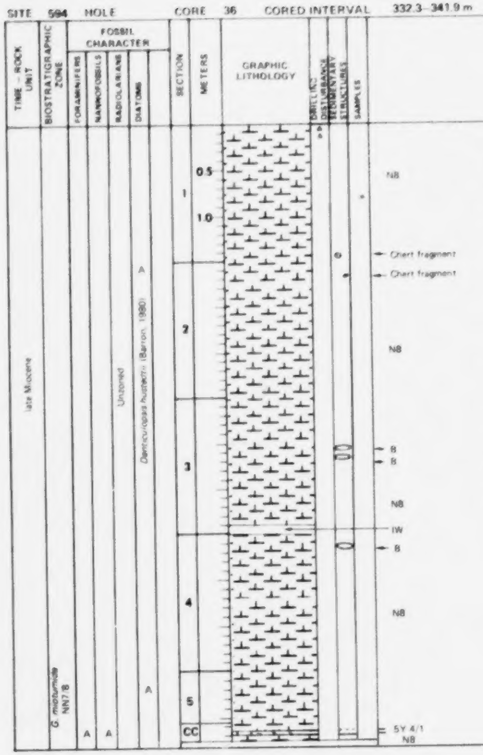
NANNOFOSSIL OOZE, very light gray (N8), subtle variations between firmer and less firm biscuits, toherwise entirely homogeneous.

SMEAR SLIDE SUMMARY:

	2, 80
	D
Composition:	
Quartz	T
Mica	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

B = biscuits

SITE 594 HOLE CORE 36 CORED INTERVAL 332.3–341.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida NN7/8
A
A
Unzoned
Denticulopsis hustedtii (Barron, 1980)
A
A
1
2
3
4
5
CC
0.5
1.0
NB
Chert fragment
Chert fragment
NB
B
B
NB
IW
B
NB
5Y 4/1
NB

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), firmer, specks of pyrite, firmer biscuits, and a chert fragment.

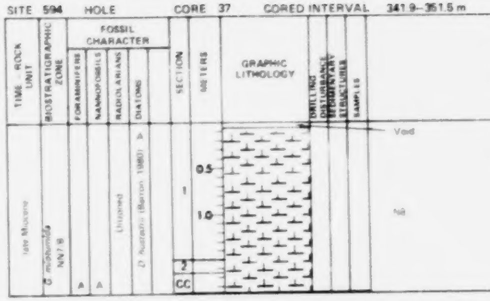
VOLCANIC ASH in Core Catcher, olive gray (5Y 4/1) grading upward to light olive gray (5Y 7/1) with sharp bottom contact.

SMEAR SLIDE SUMMARY

	1, 81 D	CC, 14 M
Composition:		
Quartz	T	R
Mica	T	T
Volcanic glass	—	A
Pyrite	T	R
Foraminifers	R	R
Calc. nannofossils	D	C
Diatoms	T	—
Sponge spicules	T	T

B = Biscuit

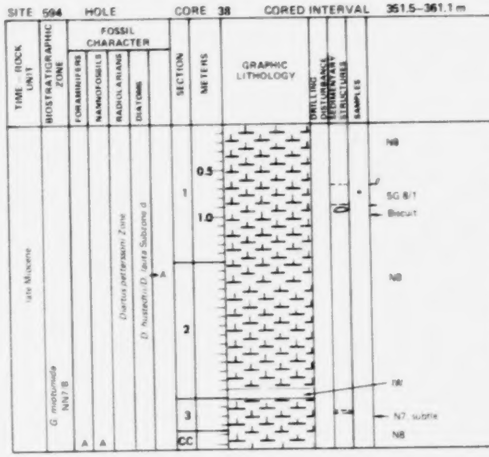
SITE 594 HOLE CORE 37 CORED INTERVAL 341.9–351.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida NN7/8
A
A
Unzoned
D. hustedtii (Barron, 1980)
A
1
2
CC
0.5
1.0
Void
NB

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), homogeneous except for a few firmer biscuits.

SITE 594 HOLE CORE 38 CORED INTERVAL 351.5–361.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
late Miocene
G. miotumida NN7/8
A
A
Diartus petterssoni Zone
D. hustedtii-D. lauta Subzone d
A
1
2
3
CC
0.5
1.0
NB
5G 8/1
Biscuit
NB
IW
N7, subtle
NB

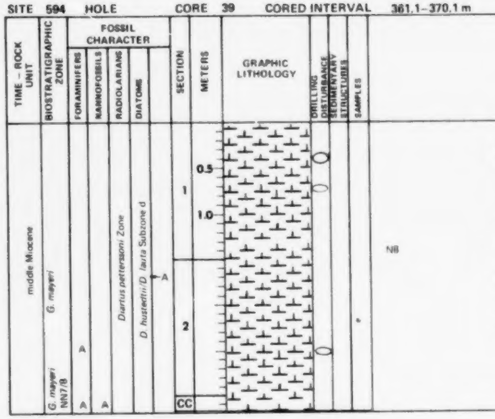
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), almost homogeneous except for iron sulfide layers (N8) and biscuits and light greenish gray (5G 8/1) layer of slightly more siliceous composition.

SMEAR SLIDE SUMMARY

	1, 84
Composition:	
Quartz	T
Mica	R
Pyrite	R
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

SITE 594 HOLE CORE 39 CORED INTERVAL 361.1–370.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri
G. mayeri NN7/8
A
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone d
A
0.5
1.0
1
2
CC
NB

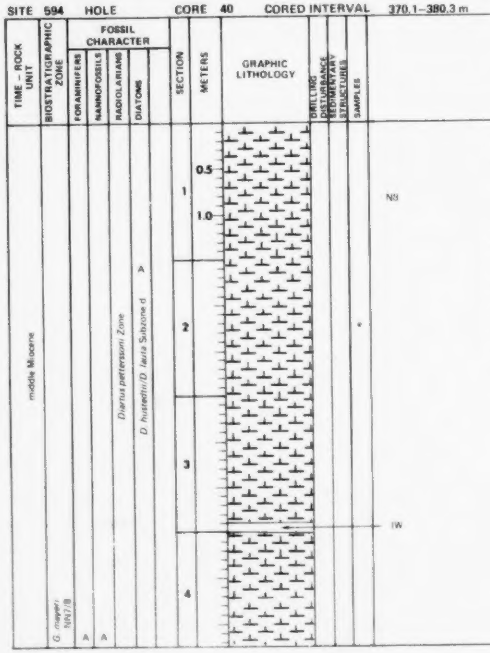
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (NB), soft with firm biscuits as shown, massive, no clear bioturbation

SMEAR SLIDE SUMMARY

	2, 70
	D
Texture	
Silt	R
Clay	D
Composition	
Mica	T
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	T

SITE 594 HOLE CORE 40 CORED INTERVAL 370.1–380.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN7/8
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone d
A
0.5
1.0
1
2
3
4
NB
IW

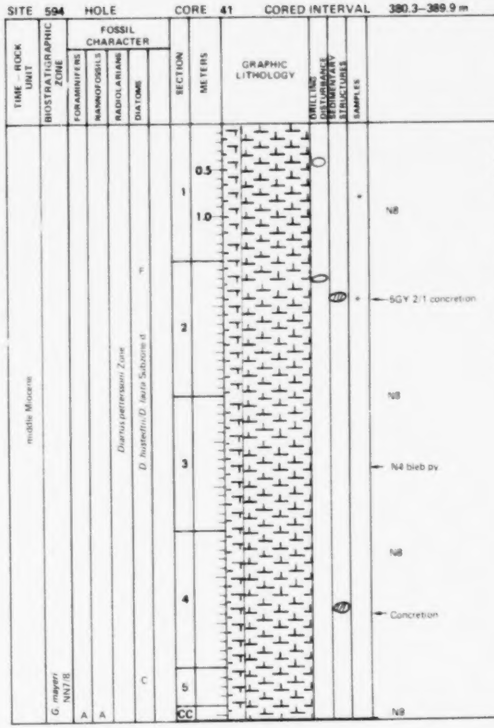
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (NB), soft, massive, bioturbation not evident

SMEAR SLIDE SUMMARY

	2, 70
	D
Texture	
Silt	C
Clay	D
Composition	
Quartz	T
Mica	T
Heavy minerals	T
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 41 CORED INTERVAL 380.3–389.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN7/8
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone d
F
C
0.5
1.0
1
2
3
4
5
CC
NB
5GY 2/1 concretion
NB
N4 bleb py
NB
Concretion
N9

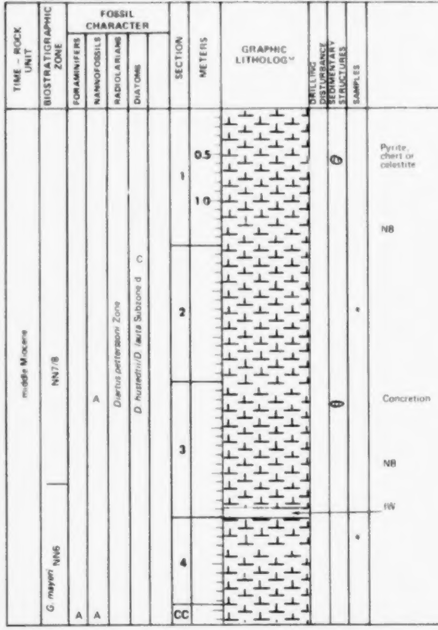
LITHOLOGIC DESCRIPTION

FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (NB), soft with biscuits where shown, pyritic concretion in Section 2, little evidence of bioturbation.

SMEAR SLIDE SUMMARY

	1, 80	2, 45
	D	M
Texture:		
Silt	C	A
Clay	D	A
Composition:		
Quartz	T	T
Mica	T	–
Pyrite	T	A
Micronodules	–	A
Foraminifers	C	–
Calc. nannofossils	D	A
Sponge spicules	R	–

SITE 594 HOLE CORE 42 CORED INTERVAL 389.9–399.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN7/8
G. mayeri NN6
A
A A
Diartus pettersoni Zone
D. hustedtii/D. lauta Subzone d
C
1
2
3
4
CC
0.5
1.0
Pyrite, chert or celestite
N8
Concretion
N8
IW

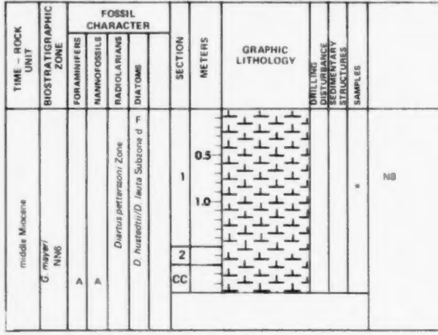
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, massive, little clear bioturbation, concretions of mixed pyrite, chert and/or celestite in Sections 1 and 3.

SMEAR SLIDE SUMMARY

	2, 70	4, 22
	D	M
Texture:		
Silt	–	C
Clay	D	D
Composition:		
Quartz	T	T
Feldspar	–	T
Mica	T	T
Glauconite	T	–
Pyrite	T	R
Foraminifers	R	C
Calc. nannofossils	D	D
Sponge spicules	T	R

SITE 594 HOLE CORE 43 CORED INTERVAL 399.5–409.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN6
A A
Diartus pettersoni Zone
D. hustedtii/D. lauta Subzone d
F
1
2
CC
0.5
1.0
N8

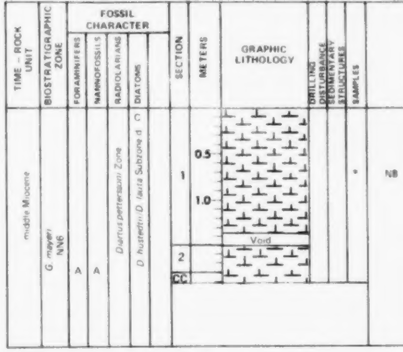
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, massive, homogeneous, little clear bioturbation.

SMEAR SLIDE SUMMARY

	1, 80
	D
Texture:	
Silt	R
Clay	D
Composition:	
Mica	T
Glauconite	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 44 CORED INTERVAL 409.1–418.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN6
A A
Diartus pettersoni Zone
D. hustedtii/D. lauta Subzone d
C
1
2
CC
0.5
1.0
Void
N8

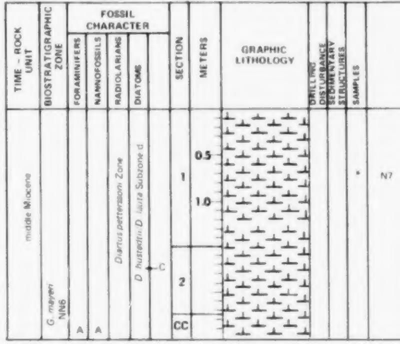
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, massive, homogeneous.

SMEAR SLIDE SUMMARY

	1, 70
	D
Texture:	
Silt	R
Clay	D
Composition:	
Mica	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 45 CORED INTERVAL 418.7–428.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. mayeri NN6
A A
Diartus pettersoni Zone
D. hustedtii/D. lauta Subzone d
C
1
2
CC
0.5
1.0
N7

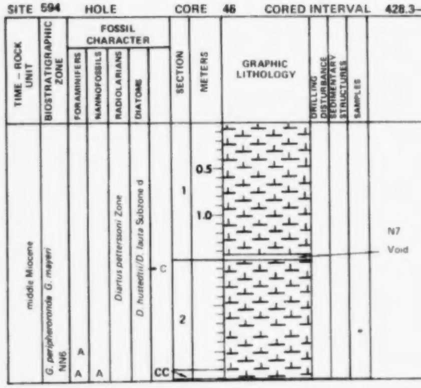
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light gray (N7), soft to stiff, little structure.

SMEAR SLIDE SUMMARY

	1, 70
	D
Texture:	
Silt	C
Clay	D
Composition:	
Quartz	T
Feldspar	T
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 46 CORED INTERVAL 428.3–437.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. peripheroronda G. mayeri
NN6
A
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone d
C
1
2
CC
0.5
1.0
N7
Void

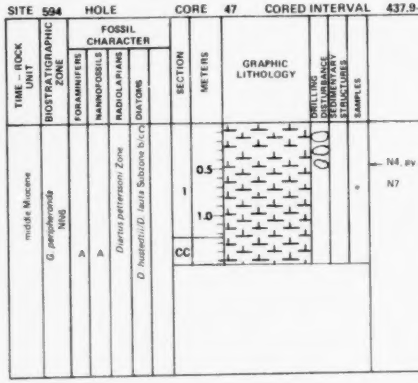
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light gray (N7), stiff, little structure

SMEAR SLIDE SUMMARY

	2, 80
	D
Texture:	
Silt	C
Clay	D
Composition:	
Quartz	T
Glauconite	T+
Pyrite	R
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 47 CORED INTERVAL 437.9–447.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. peripheroronda
NN6
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone b/c
1
CC
0.5
1.0
N4, py
N7

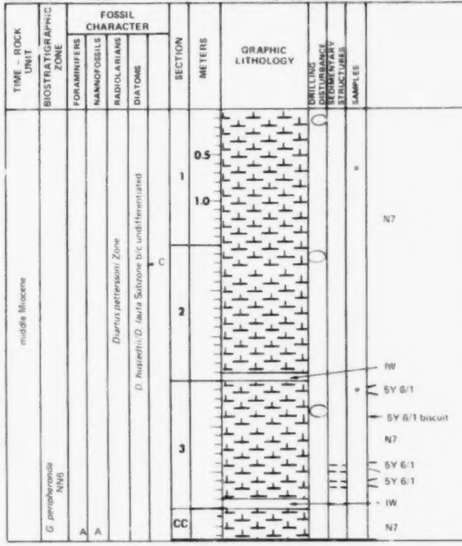
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light gray (N7), stiff, little structure, occasional biscuits as shown.

SMEAR SLIDE SUMMARY

	1, 70
	D
Texture:	
Silt	R
Clay	D
Composition:	
Quartz	T
Mica	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

SITE 594 HOLE CORE 48 CORED INTERVAL 447.5–457.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. peripheronda
NN6
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone b/c undifferentiated
C
1
2
3
CC
0.5
1.0
N7
IW
5Y 6/1
5Y 6/1 biscuit
N7
5Y 6/1
5Y 6/1
IW
N7

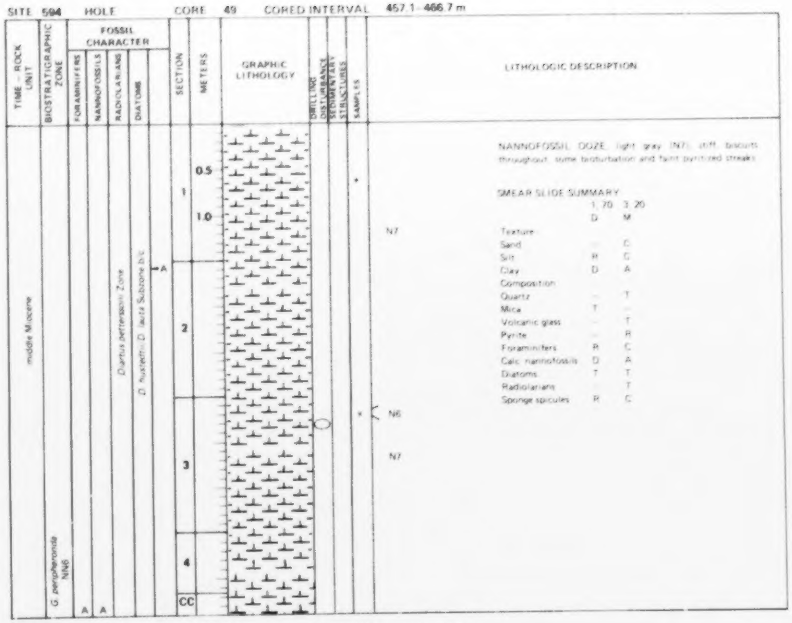
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light gray (N7), stiff, little structure, occasional sediment biscuits.

SMEAR SLIDE SUMMARY

	1, 70	3, 13
	D	M
Texture:		
Silt	C	A
Clay	D	A
Composition:		
Quartz	T	-
Glauconite	T	T
Pyrite	–	T
Foraminifers	R	R
Calc. nannofossils	D	A
Diatoms	T+	R
Radiolarians	T	R
Sponge spicules	R	C

SITE 594 HOLE CORE 49 CORED INTERVAL 457.1–466.7 m

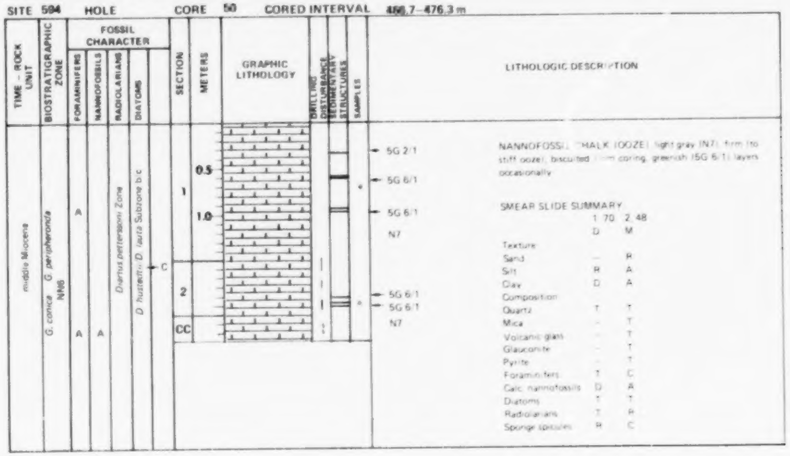

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. peripheronda
NN6
A
A
Diartus petterssoni Zone
D. hustedtii–D. lauta Subzone b/c
A
1
2
3
4
CC
0.5
1.0
N7
N6
N7

NANNOFOSSIL OOZE, light gray (N7), stiff, biscuits throughout, some bioturbation and faint pyritized streaks.

SMEAR SLIDE SUMMARY

	1, 70	3, 20
	D	M
Texture:		
Sand	–	C
Silt	R	C
Clay	D	A
Composition:		
Quartz	–	T
Mica	T	–
Volcanic glass	–	T
Pyrite	–	R
Foraminifers	R	C
Calc. nannofossils	D	A
Diatoms	T	T
Radiolarians	–	T
Sponge spicules	R	C

SITE 594 HOLE CORE 50 CORED INTERVAL 466.7–476.3 m

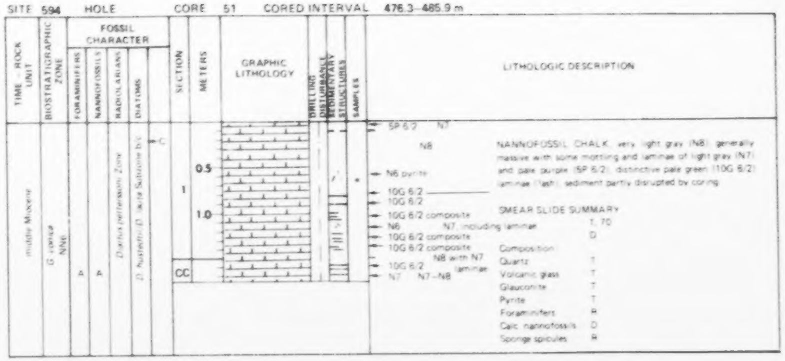

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. conica G. peripheronda
NN6
A
A
A
Diartus petterssoni Zone
D. hustedtii–D. lauta Subzone b/c
C
1
2
CC
0.5
1.0
5G 2/1
5G 6/1
5G 6/1
N7
5G 6/1
5G 6/1
N7

NANNOFOSSIL CHALK (OOZE), light gray (N7), firm (to stiff ooze), biscuited from coring, greenish (5G 6/1) layers occasionally.

SMEAR SLIDE SUMMARY

	1, 70	2, 48
	D	M
Texture:		
Sand	–	R
Silt	R	A
Clay	D	A
Composition:		
Quartz	T	T
Mica	–	T
Volcanic glass	–	T
Glauconite	–	T
Pyrite	–	T
Foraminifers	T	C
Calc. nannofossils	D	A
Diatoms	T	T
Radiolarians	T	R
Sponge spicules	R	C

SITE 594 HOLE CORE 51 CORED INTERVAL 476.3–485.9 m

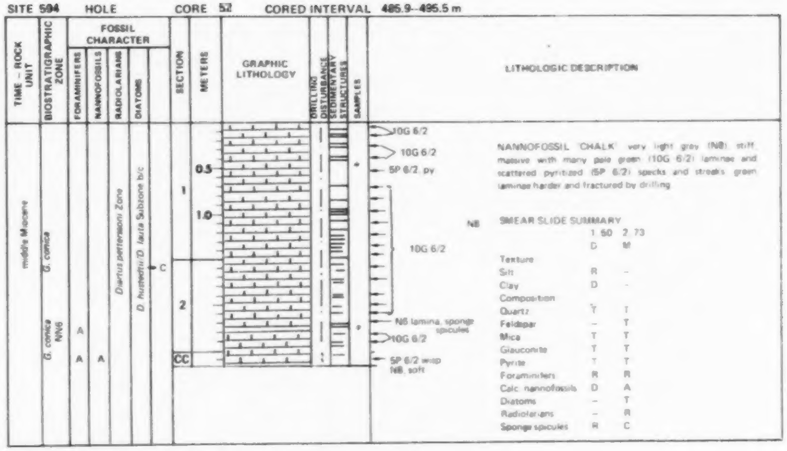

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. conica
NN6
A
A
Diartus petterssoni Zone
D. hustedtii–D. lauta Subzone b/c
C
1
CC
0.5
1.0
5P 6/2
N7
N8
N6 pyrite
10G 6/2
10G 6/2
10G 6/2 composite
N6
N7, including laminae
10G 6/2 composite
10G 6/2 composite
N8 with N7
10G 6/2
laminae
N7
N7–N8

NANNOFOSSIL CHALK, very light gray (N8), generally massive with some mottling and laminae of light gray (N7) and pale purple (5P 6/2); distinctive pale green (10G 6/2) laminae ("ash"); sediment partly disrupted by coring.

SMEAR SLIDE SUMMARY

	1, 70
	D
Composition:	
Quartz	T
Volcanic glass	T
Glauconite	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE CORE 52 CORED INTERVAL 485.9–495.5 m

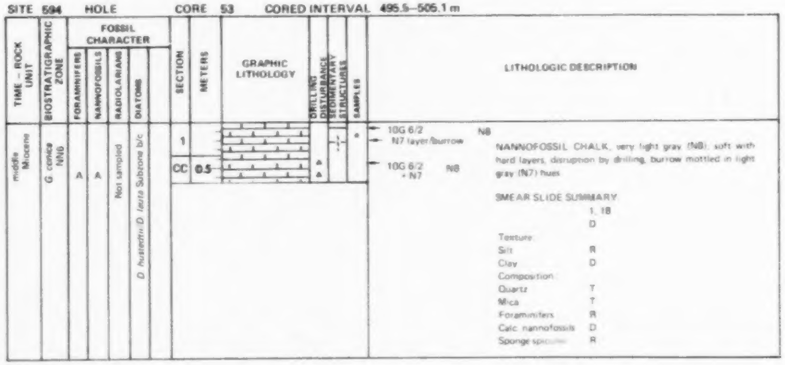

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. conica
G. conica NN6
A
A
A
Diartus petterssoni Zone
D. hustedtii/D. lauta Subzone b/c
C
1
2
CC
0.5
1.0
10G 6/2
10G 6/2
5P 6/2, py
10G 6/2
N8
N6 lamina, sponge spicules
10G 6/2
5P 6/2 wisp
N8, soft

NANNOFOSSIL "CHALK" very light gray (N8) stiff, massive with many pale green (10G 6/2) laminae and scattered pyritized (5P 6/2) specks and streaks green laminae harder and fractured by drilling

SMEAR SLIDE SUMMARY

	1, 50	2, 73
	D	M
Texture		
Silt	R	–
Clay	D	–
Composition		
Quartz	T	T
Feldspar	–	T
Mica	T	T
Glauconite	T	T
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	D	A
Diatoms	–	T
Radiolarians	–	R
Sponge spicules	R	C

SITE 594 HOLE CORE 53 CORED INTERVAL 495.5–505.1 m

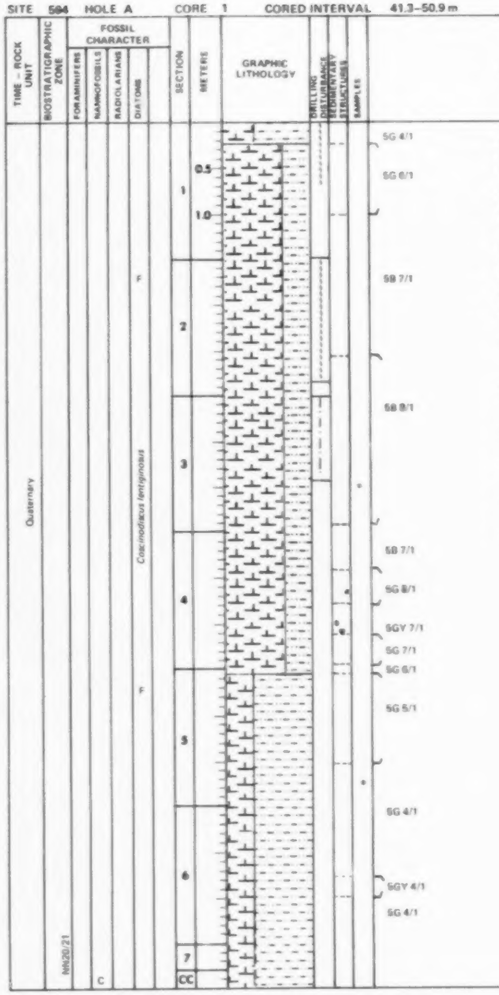

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. conica NN6
A
A
Not sampled
D. hustedtii/D. lauta Subzone b/c
1
CC
0.5
10G 6/2
N7 layer/burrow
N8
10G 6/2 + N7
N8

NANNOFOSSIL CHALK, very light gray (N8); soft with hard layers, disruption by drilling, burrow mottled in light gray (N7) hues

SMEAR SLIDE SUMMARY

	1, 18
	D
Texture:	
Silt	R
Clay	D
Composition:	
Quartz	T
Mica	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE A CORE 1 CORED INTERVAL 41.3–50.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN20/21
C
F
Coscinodiscus lentiginosus
F
1
2
3
4
5
6
7
CC
0.5
1.0
5G 4/1
5G 6/1
5B 7/1
5B 8/1
5B 7/1
5G 8/1
5GY 7/1
5G 7/1
5G 6/1
5G 5/1
5G 4/1
5GY 4/1
5G 4/1

LITHOLOGIC DESCRIPTION

DIATOM, SPONGE SPICULE, NANNOFOSSIL BEARING CLAYEY SILT, dark greenish gray to greenish gray (5G 4/1 to 5G 8/1)

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1), with pyrite specks, otherwise homogeneous, some yellowish iron oxide(?) streaks. H_2S odor.

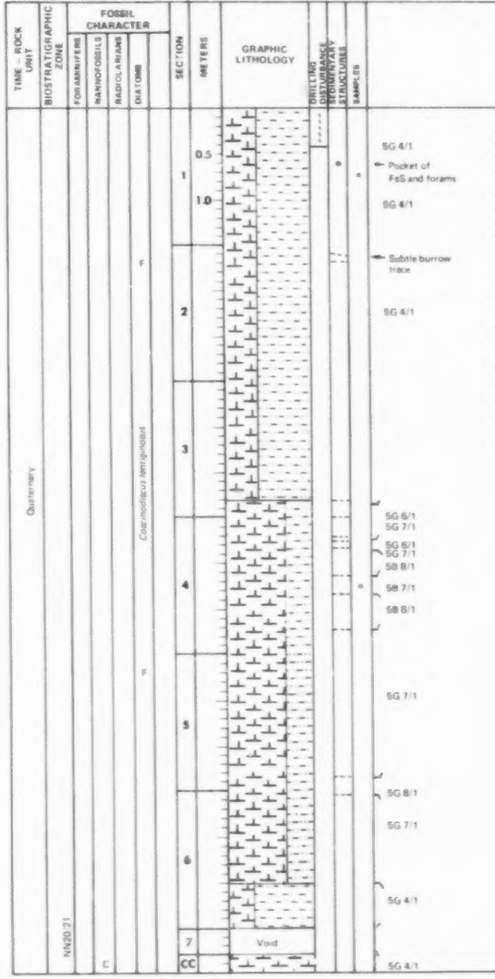
Light greenish gray (5G 8/1) to greenish gray (5G 6/1) lithology is intermediate in amount of terrigenous component.

Pockets of foraminifer rich sediment at Section 4, 70, 98, and 110 cm.

SMEAR SLIDE SUMMARY

	3, 99	5, 125
	D	D
Composition:		
Quartz	R	A
Feldspar	T	R
Heavy minerals	T	T
Volcanic glass	T	—
Clay minerals	—	C
Mica	R	A
Pyrite	—	R
Foraminifers	C	R
Calc. nannofossils	A	C
Radiolarians	—	T
Diatoms	T	C
Sponge spicules	R	C

SITE 594 HOLE A CORE 2 CORED INTERVAL 50.9–60.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN20/21
C
F
Coscinodiscus lentiginosus
F
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5G 4/1
Pocket of FeS and forams
5G 4/1
Subtle burrow trace
5G 4/1
5G 6/1
5G 7/1
5G 6/1
5G 7/1
5B 8/1
5B 7/1
5B 8/1
5G 7/1
5G 8/1
5G 7/1
5G 4/1
5G 4/1

LITHOLOGIC DESCRIPTION

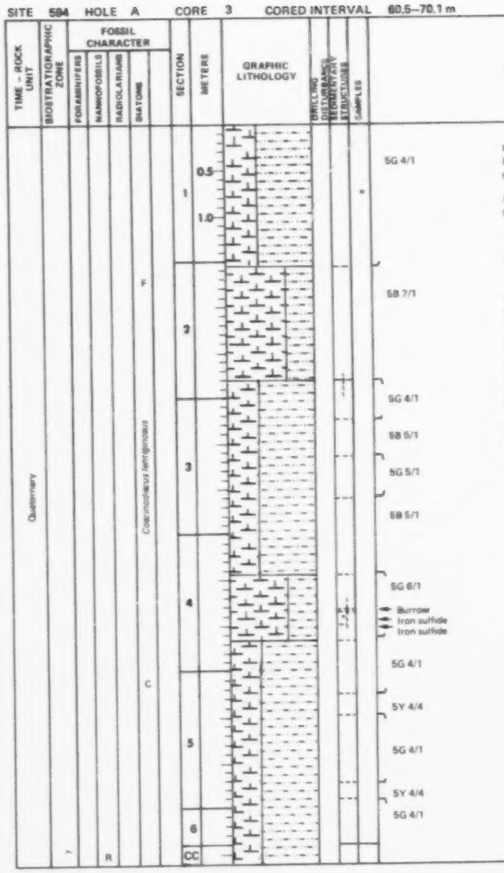
NANNOFOSSIL-BEARING CLAYEY SILT TO SILT-BEARING NANNOFOSSIL OOZE, dark green (5G 4/1) to lighter green (5G 6/1), homogeneous, minor pyrite throughout.

MICA, QUARTZ AND FORAMINIFER-BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1 to 5B 8/1) with moderate bioturbation, pryite staining and pockets. H_2S odor.

SMEAR SLIDE SUMMARY

	1, 72	4, 72
	D	D
Composition:		
Quartz	C	C
Heavy minerals	T	—
Mica	C	C
Pyrite	T	T
Foraminifers	R	C
Calc. nannofossils	A	A
Radiolarians	T	—
Diatoms	R	R
Sponge spicules	R	R

SITE 594 HOLE A CORE 3 CORED INTERVAL 60.5–70.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
Coscinodiscus lentiginosus
F
C
R
1
2
3
4
5
6
CC
0.5
1.0
5G 4/1
5B 7/1
5G 4/1
5B 6/1
5G 5/1
5B 5/1
5G 6/1
Burrow
Iron sulfide
Iron sulfide
5G 4/1
5Y 4/4
5G 4/1
5Y 4/4
5G 4/1

LITHOLOGIC DESCRIPTION

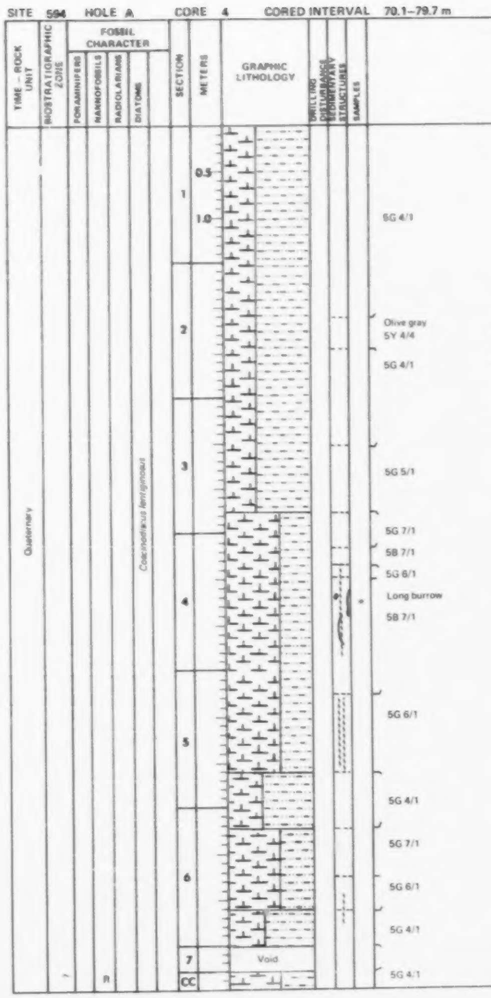
NANNOFOSSIL-, DIATOM-, AND SPONGE SPICULE BEARING CLAYEY SILT, dark green (5G 4/1), homogeneous.

FORAMINIFER BEARING NANNOFOSSIL OOZE, light bluish gray (5B 7/1). H_2S odor.

SMEAR SLIDE SUMMARY

	1, 75
	D
Composition:	
Quartz	A
Feldspar	T
Heavy minerals	T
Clay minerals	C
Mica	C
Pyrite	T
Foraminifers	R
Calc. nannofossils	C
Radiolarians	T
Diatoms	C
Sponge spicules	C

SITE 594 HOLE A CORE 4 CORED INTERVAL 70.1–79.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
Coscinodiscus lentiginosus
R
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5G 4/1
Olive gray
5Y 4/4
5G 4/1
5G 5/1
5G 7/1
5B 7/1
5G 6/1
Long burrow
5B 7/1
5G 6/1
5G 4/1
5G 7/1
5G 6/1
5G 4/1
5G 4/1

LITHOLOGIC DESCRIPTION

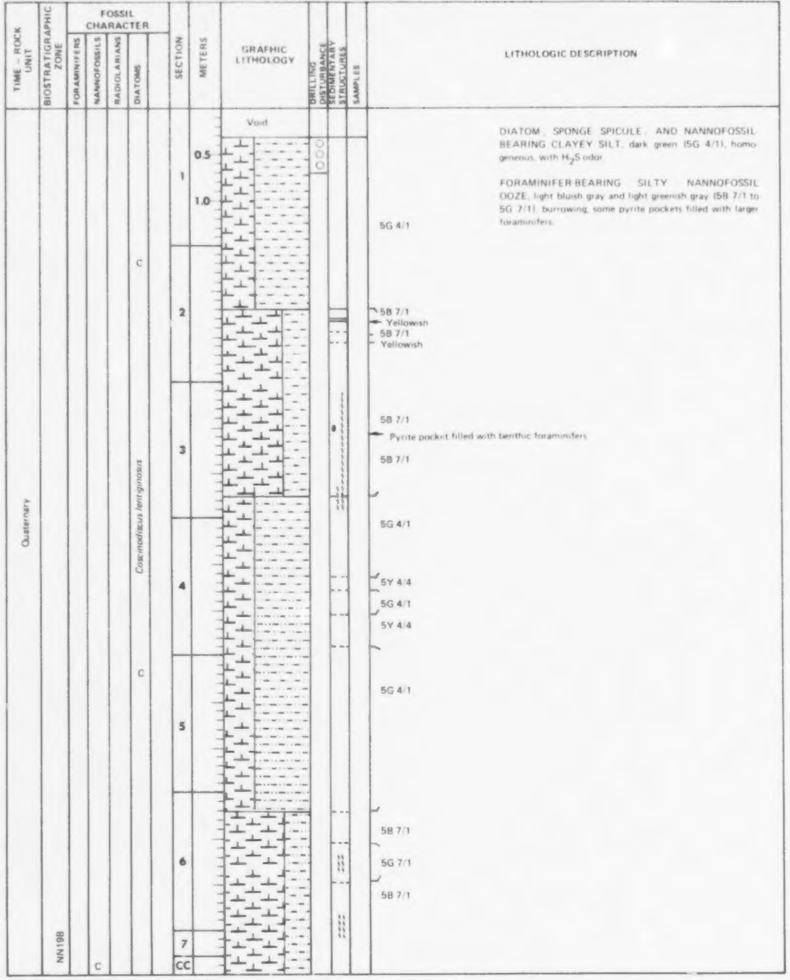
DIATOM-, SPONGE SPICULE-, AND NANNOFOSSIL BEARING CLAYEY SILT, dark green (5G 4/1), homogeneous, abundant H_2S.

QUARTZ-, MICA- AND FORAMINIFER-BEARING NANNOFOSSIL OOZE, light blue gray (5B 7/1), burrowed, stained with iron sulfide.

SMEAR SLIDE SUMMARY:

	4, 78
	D
Composition:	
Quartz	C
Heavy minerals	T
Mica	C
Pyrite	T
Foraminifers	C
Calc. nannofossils	A
Diatoms	T
Sponge spicules	R

SITE 594 HOLE A CORE 5 CORED INTERVAL 79.7–89.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN19B
C
C
Coscinodiscus lentiginosus
C
1
2
3
4
5
6
7
CC
0.5
1.0
Void
5G 4/1
5B 7/1
Yellowish
5B 7/1
Yellowish
5B 7/1
5B 7/1
5G 4/1
5Y 4/4
5G 4/1
5Y 4/4
5G 4/1
5B 7/1
5G 7/1
5B 7/1

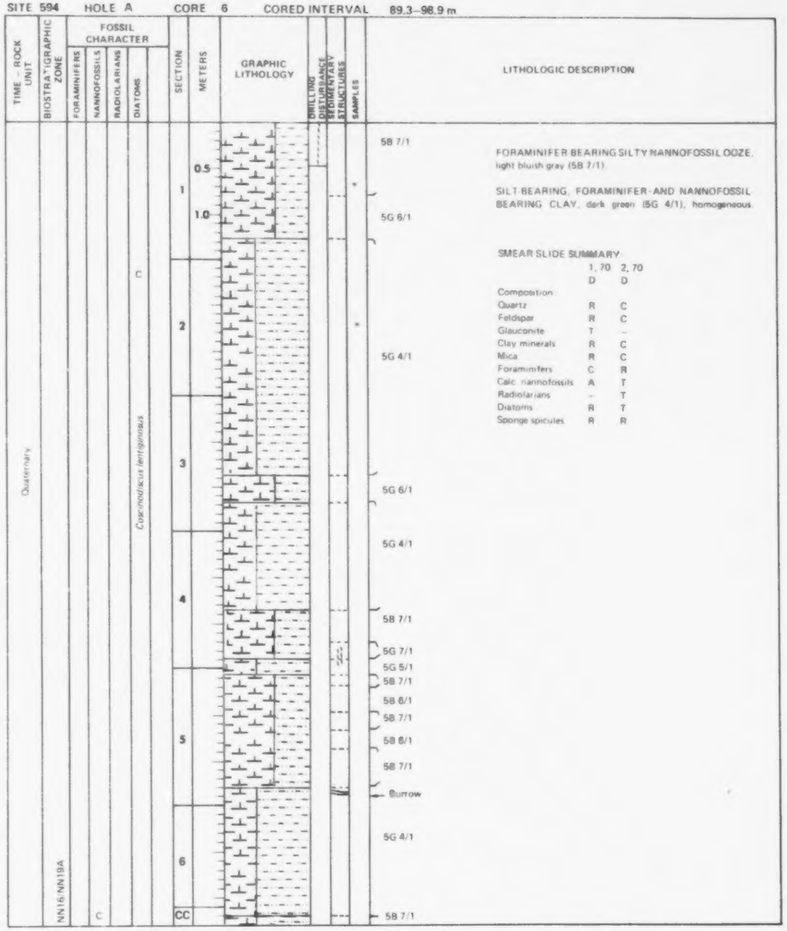
LITHOLOGIC DESCRIPTION

DIATOM, SPONGE SPICULE, AND NANNOFOSSIL BEARING CLAYEY SILT, dark green (5G 4/1), homogeneous, with H_2S odor

FORAMINIFER-BEARING SILTY NANNOFOSSIL OOZE, light bluish gray and light greenish gray (5B 7/1 to 5G 7/1), burrowing, some pyrite pockets filled with larger foraminifers.

Pyrite pocket filled with benthic foraminifers

SITE 594 HOLE A CORE 6 CORED INTERVAL 89.3–98.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
Quaternary
NN16/NN19A
C
C
Coscinodiscus lentiginosus
1
2
3
4
5
6
CC
0.5
1.0
5B 7/1
5G 6/1
5G 4/1
5G 6/1
5G 4/1
5B 7/1
5G 7/1
5G 5/1
5B 7/1
5B 6/1
5B 7/1
5B 6/1
5B 7/1
Burrow
5G 4/1
5B 7/1

LITHOLOGIC DESCRIPTION

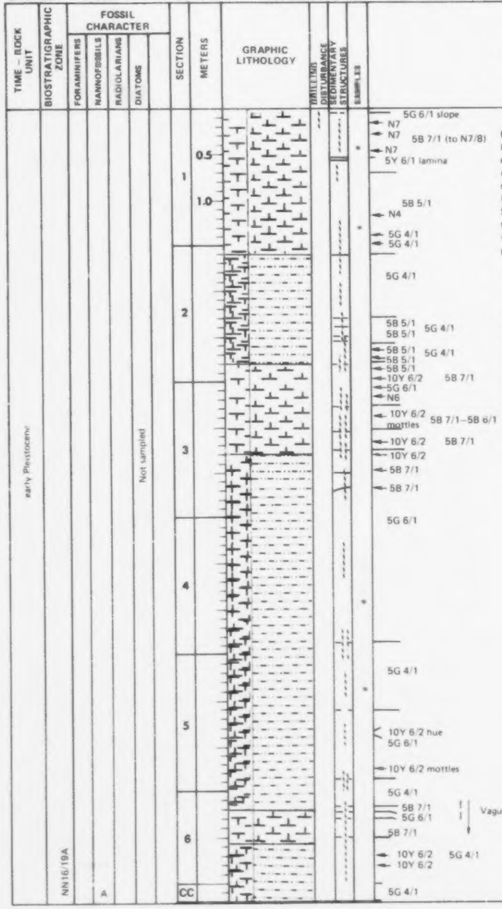
FORAMINIFER BEARING SILTY NANNOFOSSIL OOZE, light bluish gray (5B 7/1).

SILT-BEARING, FORAMINIFER-AND NANNOFOSSIL BEARING CLAY, dark green (5G 4/1), homogeneous.

SMEAR SLIDE SUMMARY

	1, 70 D	2, 70 D
Composition:		
Quartz	R	C
Feldspar	R	C
Glauconite	T	–
Clay minerals	R	C
Mica	R	C
Foraminifers	C	R
Calc. nannofossils	A	T
Radiolarians	–	T
Diatoms	R	T
Sponge spicules	R	R

SITE 594 HOLE A CORE 7 CORED INTERVAL 98.9–108.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
NN16/19A
A
Not sampled
1
2
3
4
5
6
CC
0.5
1.0
5G 6/1 slope
N7
N7
5B 7/1 (to N7/8)
N7
5Y 6/1 lamina
5B 5/1
N4
5G 4/1
5G 4/1
5G 4/1
5B 5/1
5B 5/1
5G 4/1
5B 5/1
5B 5/1
5B 5/1
5G 4/1
10Y 6/2
5B 7/1
5G 6/1
N6
10Y 6/2 mottles
5B 7/1–5B 6/1
10Y 6/2
5B 7/1
10Y 6/2
5B 7/1
5B 7/1
5G 6/1
5G 4/1
10Y 6/2 hue
5G 6/1
10Y 6/2 mottles
5G 4/1
5B 7/1
5G 6/1
Vague
5B 7/1
10Y 6/2
10Y 6/2
5G 4/1
5G 4/1

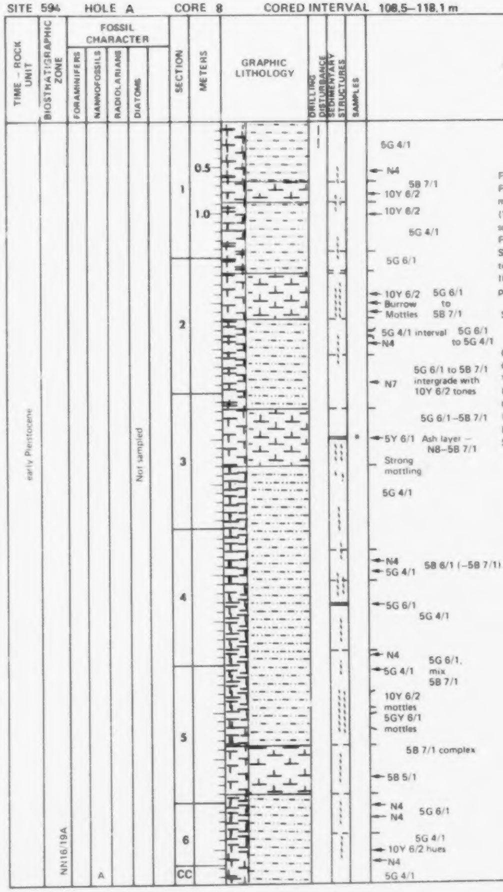
LITHOLOGIC DESCRIPTION

FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, bluish gray (5B 7/1 to 5B 5/1), soft, massive with prominent burrow mottles of pale olive (10Y 6/2), occasional pyritized streaks and blebs (N4), subtle color shades gradational and interbedded with FORAMINIFER-, NANNOFOSSIL-, AND/OR SPONGE SPICULE-BEARING CLAYEY SILT, greenish gray (5G 6/1 to 5G 4/1), soft, massive, burrow mottled as in FORAMINIFER- (AND CLAY-) BEARING NANNOFOSSIL OOZE, pyrite (N4) blebs.

SMEAR SLIDE SUMMARY

	1, 40	1, 130	4, 87	5, 40
Composition:				
Quartz	R	R	C	C
Feldspar	T	T	T	R
Heavy minerals	—	T	T	—
Clay minerals	R	C	C	C
Mica	T	R	R	C
Foraminifers	C	C	C	R
Calc. nannofossils	A	A	C	R
Radiolarians	—	—	—	T
Diatoms	—	T	T	T
Sponge spicules	R	R	R	C

SITE 594 HOLE A CORE 8 CORED INTERVAL 108.5–118.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
NN16/19A
A
Not sampled
1
2
3
4
5
6
CC
0.5
1.0
5G 4/1
N4
5B 7/1
10Y 6/2
10Y 6/2
5G 4/1
5G 6/1
10Y 6/2
Burrow
Mottles
5G 6/1 to 5B 7/1
5G 4/1 interval
N4
5G 6/1 to 5G 4/1
N7
5G 6/1 to 5B 7/1 intergrade with 10Y 6/2 tones
5G 6/1–5B 7/1
5Y 6/1
Ash layer – N8–5B 7/1
Strong mottling
5G 4/1
N4
5G 4/1
5B 6/1 (–5B 7/1)
5G 6/1
5G 4/1
N4
5G 4/1
5G 6/1, mix 5B 7/1
10Y 6/2 mottles
5GY 6/1 mottles
5B 7/1 complex
5B 5/1
N4
N4
5G 6/1
5G 4/1
10Y 6/2 hues
N4
5G 4/1

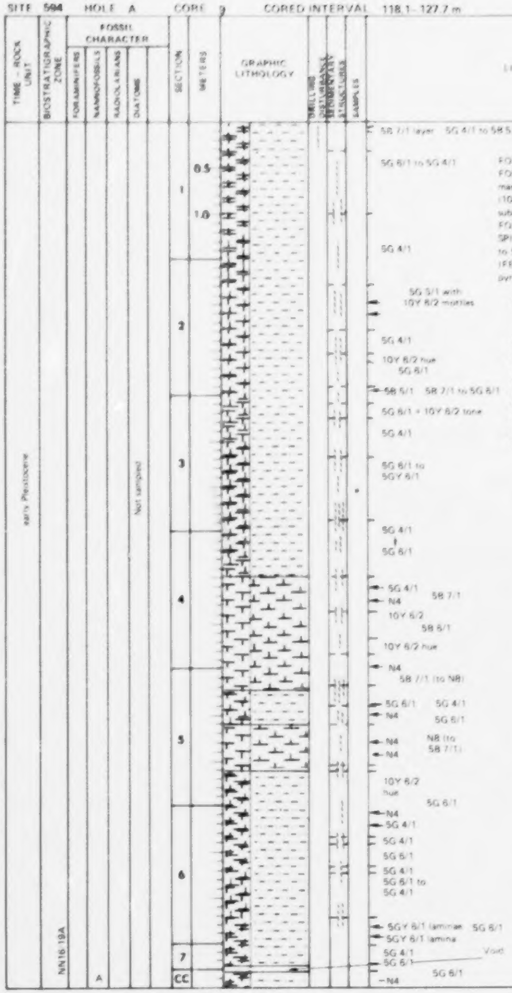
LITHOLOGIC DESCRIPTION

FORAMINIFER- (AND CLAY-) BEARING NANNOFOSSIL OOZE, bluish gray (5B 7/1 to 5B 5/1), soft, massive with prominent burrow mottles of pale olive (10Y 6/2), occasional pyritized streaks and blebs (N4), subtle color shades gradational and interbedded with FORAMINIFER-, NANNOFOSSIL-, AND/OR SPONGE SPICULE-BEARING CLAYEY SILT, greenish gray (5G 6/1 to 5G 4/1), soft, massive, burrow mottled as in FORAMINIFER- (AND CLAY-) BEARING NANNOFOSSIL OOZE, pyrite (N4) blebs.

SMEAR SLIDE SUMMARY:

	3, 51 M
Composition:	
Quartz	T
Volcanic glass	D
Foraminifers	C
Calc. nannofossils	C
Radiolarians	T
Diatoms	T
Sponge spicules	T

SITE 594 HOLE A CORE 9 CORED INTERVAL 118.1–127.7 m

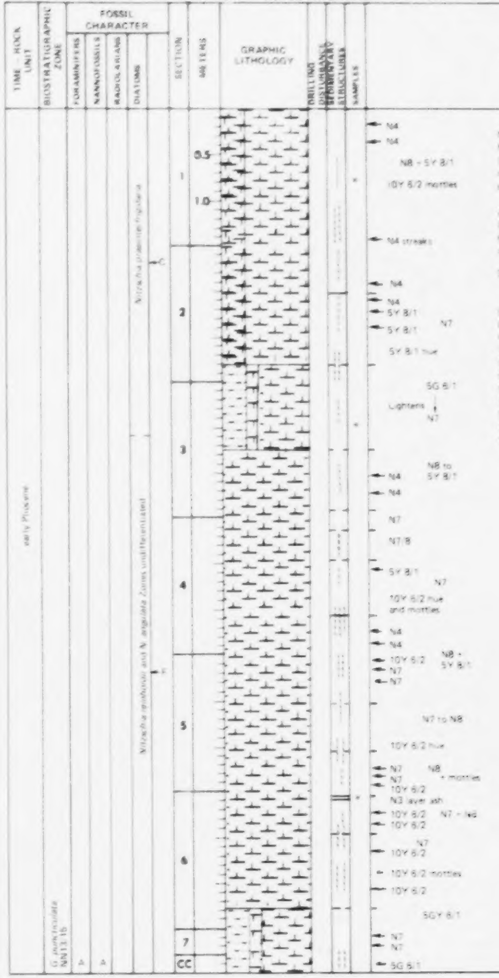

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pleistocene
NN16/18A
A
Not sampled
1
2
3
4
5
6
7
CC
0.5
1.0
5B 7/1 layer
5G 4/1 to 5B 5/1
5G 6/1 to 5G 4/1
5G 4/1
5G 5/1 with 10Y 6/2 mottles
5G 4/1
10Y 6/2 hue
5G 6/1
5B 5/1
5B 7/1 to 5G 6/1
5G 6/1 + 10Y 6/2 tone
5G 4/1
5G 6/1 to 5GY 6/1
5G 4/1
5G 6/1
5G 4/1
N4
5B 7/1
10Y 6/2
5B 6/1
10Y 6/2 hue
N4
5B 7/1 (to N8)
5G 6/1
5G 4/1
N4
5G 6/1
N4
N4
N8 (to 5B 7/1)
10Y 6/2 hue
5G 6/1
N4
5G 4/1
5G 4/1
5G 6/1
5G 4/1
5G 6/1 to 5G 4/1
5GY 6/1 laminae
5G 6/1
5GY 6/1 lamina
5G 4/1
5G 6/1
Void
5G 6/1
N4

FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, bluish gray (5B 7/1 to 5B 5/1), soft massive with prominent burrow mottles of pale olive (10Y 6/2), occasional pyritized streaks and blebs (N4), subtle color shades gradational and interbedded with FORAMINIFER, NANNOFOSSIL, AND/OR SPONGE SPICULE BEARING CLAYEY SILT, greenish gray (5G 6/1 to 5G 4/1), soft, massive, burrow mottled as in FORAMINIFER (AND CLAY) BEARING NANNOFOSSIL OOZE, pyrite (N4) blebs.

SMEAR SLIDE SUMMARY

	3, 113
	D
Composition:	
Quartz	C
Volcanic glass	T
Glauconite	T
Clay minerals	C
Mica	R
Foraminifers	C
Calc. nannofossils	A
Sponge spicules	R

SITE 594 HOLE A CORE 10 CORED INTERVAL 149.9–159.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Pliocene
G. puncticulata
NN13/15
A
A
Nitzschia praereinholdii
C
Nitzschia reinholdii and N. angulata Zones undifferentiated
F
1
2
3
4
5
6
7
CC
0.5
1.0
N4
N4
N8 – 5Y 8/1
10Y 6/2 mottles
N4 streaks
N4
N4
5Y 8/1
5Y 8/1
N7
5Y 8/1 hue
5G 6/1
Lightens
N7
N8 to 5Y 8/1
N4
N4
N7
N7/8
5Y 8/1
N7
10Y 6/2 hue and mottles
N4
N4
10Y 6/2
N7
N7
N8 + 5Y 8/1
N7 to N8
10Y 6/2 hue
N7
N7
N8
+ mottles
10Y 6/2
N3 layer ash
10Y 6/2
N7 – N8
10Y 6/2
N7
10Y 6/2
10Y 6/2 mottles
10Y 6/2
5GY 6/1
N7
N7
5G 6/1

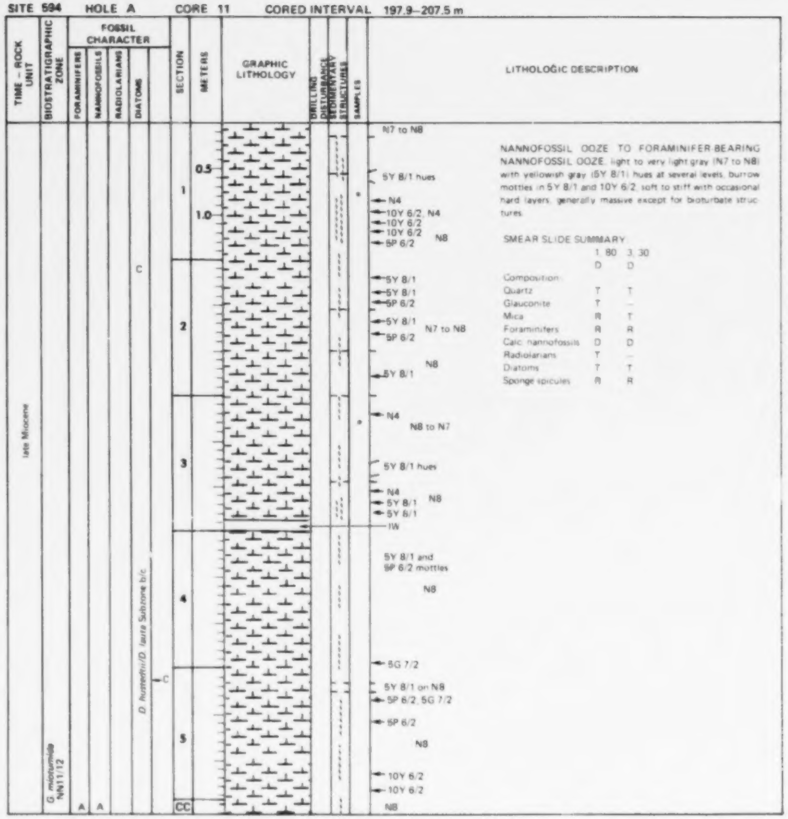
NANNOFOSSIL OOZE TO FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7) with yellowish gray (5Y 8/1) overtones, soft but stiff, massive, burrow mottled in pale olive (10Y 6/2) hues and scattered pyritized (N4) blebs and streaks.

As for NANNOFOSSIL OOZE TO FORAMINIFER-BEARING NANNOFOSSIL OOZE but with greenish (5G 6/1) to yellowish (5GY 6/1) tones, commonly CLAY- AND/OR SILT-BEARING.

SMEAR SLIDE SUMMARY

	1, 79	3, 46	6, 8
	D	D	M
Composition:			
Quartz	R	R	C
Heavy minerals	T	T	–
Volcanic glass	–	–	A
Glauconite	T	T	–
Clay minerals	R	R	–
Mica	T	T	–
Foraminifers	C	R	T
Calc. nannofossils	A	D	R
Diatoms	–	T	–
Sponge spicules	R	R	–

SITE 594 HOLE A CORE 11 CORED INTERVAL 197.9–207.5 m

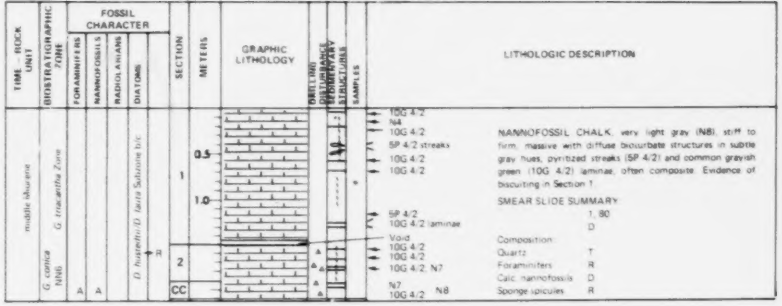

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
late Miocene
G. miotumida
NN11/12
A
A
C
D. hustedtii/D. lauta Subzone b/c
C
1
2
3
4
5
CC
0.5
1.0
N7 to N8
5Y 8/1 hues
N4
10Y 6/2, N4
10Y 6/2
10Y 6/2
5P 6/2
N8
5Y 8/1
5Y 8/1
5P 6/2
5Y 8/1
5P 6/2
N7 to N8
N8
5Y 8/1
N4
N8 to N7
5Y 8/1 hues
N4
5Y 8/1
5Y 8/1
N8
IW
5Y 8/1 and
5P 6/2 mottles
N8
5G 7/2
5Y 8/1 on N8
5P 6/2, 5G 7/2
5P 6/2
N8
10Y 6/2
10Y 6/2
N8

NANNOFOSSIL OOZE TO FORAMINIFER-BEARING NANNOFOSSIL OOZE, light to very light gray (N7 to N8) with yellowish gray (5Y 8/1) hues at several levels, burrow mottles in 5Y 8/1 and 10Y 6/2, soft to stiff with occasional hard layers, generally massive except for bioturbate structures.

SMEAR SLIDE SUMMARY

	1, 80	3, 30
	D	D
Composition:		
Quartz	T	T
Glauconite	T	–
Mica	R	T
Foraminifers	R	R
Calc. nannofossils	D	D
Radiolarians	T	–
Diatoms	T	T
Sponge spicules	R	R

SITE 594 HOLE A CORE 12 CORED INTERVAL 495.5–505.1 m

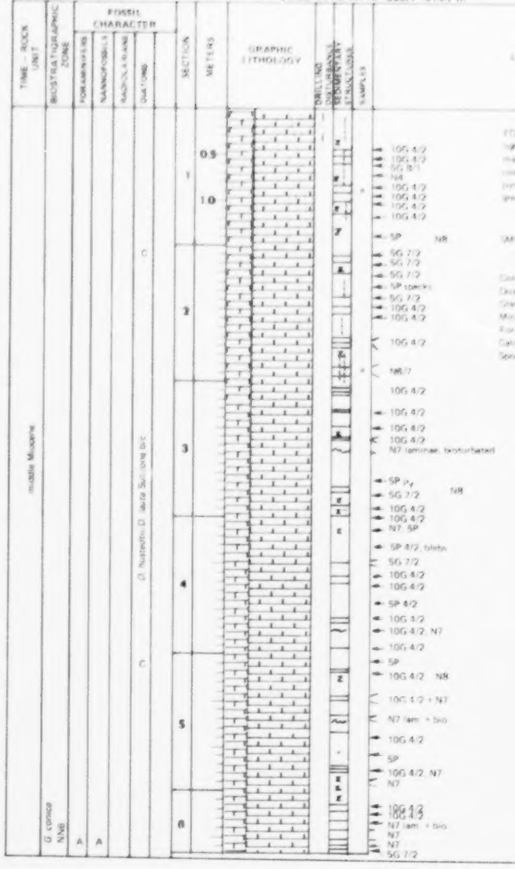

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
LITHOLOGIC DESCRIPTION
middle Miocene
G. trilobus/G. fohsi Zone
G. conica
NN6
A
A
D. hustedtii/D. lauta Subzone b/c
R
1
2
CC
0.5
1.0
10G 4/2
N4
10G 4/2
5P 4/2 streaks
10G 4/2
10G 4/2
5P 4/2
10G 4/2 laminae
Void
10G 4/2
10G 4/2
10G 4/2, N7
N7
10G 4/2
N8

NANNOFOSSIL CHALK, very light gray (N8), stiff to firm, massive with diffuse bioturbate structures in subtle gray hues, pyritized streaks (5P 4/2) and common grayish green (10G 4/2) laminae, often composite. Evidence of biscuiting in Section 1.

SMEAR SLIDE SUMMARY

	1, 80
	D
Composition:	
Quartz	T
Foraminifers	R
Calc. nannofossils	D
Sponge spicules	R

SITE 594 HOLE A CORE 13 CORED INTERVAL 506.1–514.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. conica
NN6
A
A
C
D. hustedtii–D. lauta Subzone b/c
C
1
2
3
4
5
6
0.5
1.0
10G 4/2
10G 4/2
5G 8/1
N4
10G 4/2
10G 4/2
10G 4/2
10G 4/2
5P
N8
5G 7/2
5G 7/2
5G 7/2
5P specks
5G 7/2
10G 4/2
10G 4/2
10G 4/2
N8/7
10G 4/2
10G 4/2
10G 4/2
10G 4/2
N7 laminae, bioturbated
5P Py
5G 7/2
N8
10G 4/2
10G 4/2
N7, 5P
5P 4/2, blebs
5G 7/2
10G 4/2
10G 4/2
5P 4/2
10G 4/2
10G 4/2, N7
10G 4/2
5P
10G 4/2 N8
10G 4/2 + N7
N7 lam. + bio.
10G 4/2
5P
10G 4/2, N7
N7
10G 4/2
10G 4/2
N7 lam. + bio.
N7
N7
5G 7/2

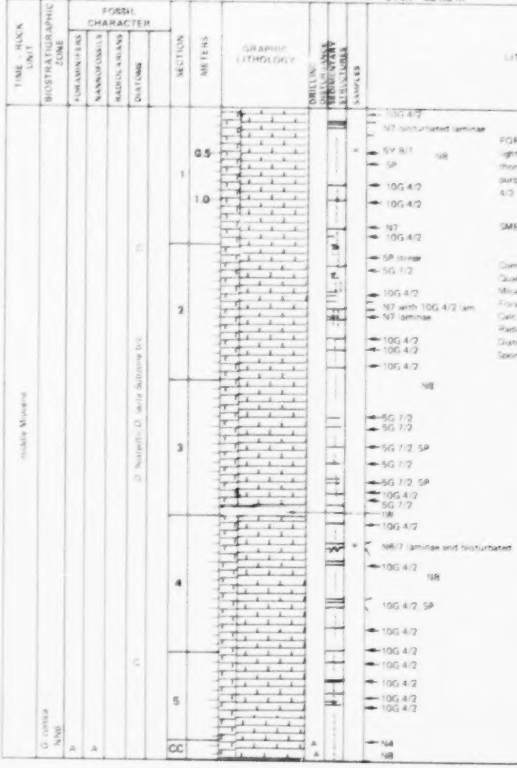
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), firm (but biscuiting produces soft sections), massive but thoroughly bioturbated (includes *Zoophycos*, *Chondrites*, and *Planolites*) and mottled; common purplish (5P) specks and streaks; conspicuous secondary green (10G 4/2 to 5G 7/2) color laminae throughout.

SMEAR SLIDE SUMMARY

	1, 88	2, 136
	D	M
Composition:		
Quartz	T	R
Glauconite	–	T
Mica	T	T
Foraminifers	C	C
Calc. nannofossils	D	A
Sponge spicules	R	C

SITE 594 HOLE A CORE 14 CORED INTERVAL 514.7–524.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. conica
NN6
A
A
C
D. hustedtii–D. lauta Subzone b/c
C
1
2
3
4
5
CC
0.5
1.0
10G 4/2
N7 bioturbated laminae
5Y 8/1
N8
5P
10G 4/2
10G 4/2
N7
10G 4/2
5P streak
5G 7/2
10G 4/2
N7 with 10G 4/2 lam.
N7 laminae
10G 4/2
10G 4/2
10G 4/2
N8
5G 7/2
5G 7/2
5G 7/2, 5P
5G 7/2
5G 7/2, 5P
10G 4/2
5G 7/2
IW
10G 4/2
N8/7 laminae and bioturbated
10G 4/2
N8
10G 4/2, 5P
10G 4/2
10G 4/2
10G 4/2
10G 4/2
10G 4/2
10G 4/2
N4
N8

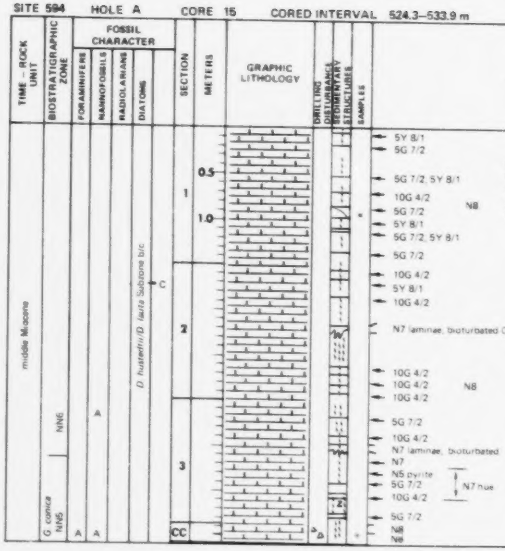
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, very light gray (N8), firm but soft portions due to biscuiting, thoroughly bioturbated and burrow mottled with common purplish (5P) streaks and blebs; conspicuous green (10G 4/2 and 5G 7/2) color laminae. Occasional *Zoophycos*.

SMEAR SLIDE SUMMARY

	1, 48	4, 31
	D	M
Composition:		
Quartz	–	T
Mica	–	T
Foraminifers	C	R
Calc. nannofossils	D	A
Radiolarians	T	T
Diatoms	T	T
Sponge spicules	R	C

SITE 594 HOLE A CORE 15 CORED INTERVAL 524.3–533.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
NN6
G. conica
NN5
A
A
A
D. hustedtii/D. lauta Subzone b/c
C
1
2
3
CC
0.5
1.0
5Y 8/1
5G 7/2
5G 7/2, 5Y 8/1
10G 4/2
5G 7/2
N8
5Y 8/1
5G 7/2, 5Y 8/1
5G 7/2
10G 4/2
5Y 8/1
10G 4/2
N7 laminae, bioturbated C/P burrows
10G 4/2
10G 4/2
N8
10G 4/2
5G 7/2
10G 4/2
N7 laminae, bioturbated
N7
N5 pyrite
5G 7/2
N7 hue
10G 4/2
5G 7/2
N8
N8

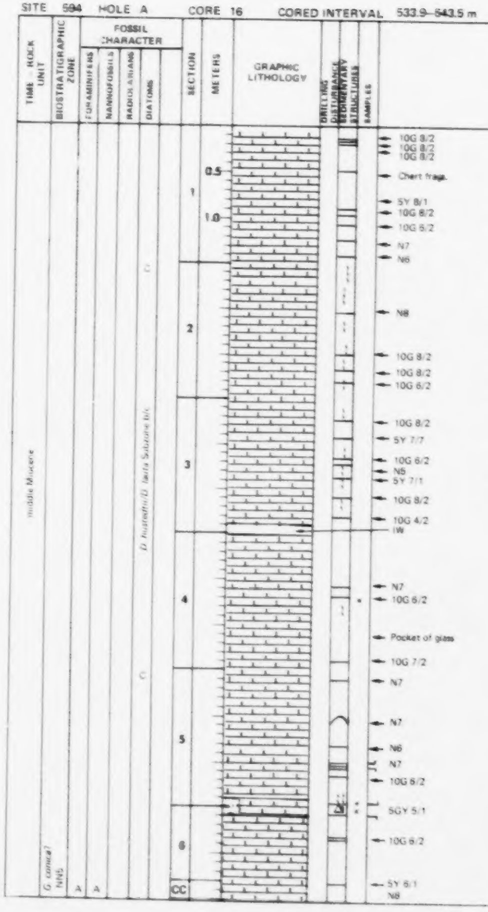
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), firm, massive but thoroughly bioturbated and swirled in colors of yellowish gray (5Y 8/1), light gray (N7) and purples (5P), scattered pyrite specks; prominent green (10G 4/2 to 5G 7/2) color laminae. *Planolites* like burrows.

SMEAR SLIDE SUMMARY

	1, 75	CC
	D	M
Composition:		
Quartz	–	R
Feldspar	–	T
Clay minerals	–	C
Mica	–	C
Foraminifers	R	R
Calc. nannofossils	D	A
Radiolarians	–	T
Diatoms	–	R
Sponge spicules	R	C

SITE 594 HOLE A CORE 16 CORED INTERVAL 533.9–543.5 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
G. conica?
NN5
A
A
D. hustedtii/D. lauta Subzone b/c
C
C
1
2
3
4
5
6
CC
0.5
1.0
10G 8/2
10G 8/2
10G 8/2
Chert frag.
5Y 8/1
10G 8/2
10G 6/2
N7
N6
N8
10G 8/2
10G 8/2
10G 6/2
10G 8/2
5Y 7/7
10G 6/2
N5
5Y 7/1
10G 8/2
10G 4/2
IW
N7
10G 6/2
Pocket of glass
10G 7/2
N7
N7
N6
N7
10G 6/2
5GY 5/1
10G 6/2
5Y 6/1
N8

LITHOLOGIC DESCRIPTION

ENTIRE CORE BROKEN INTO BISCUITS BY CORING.

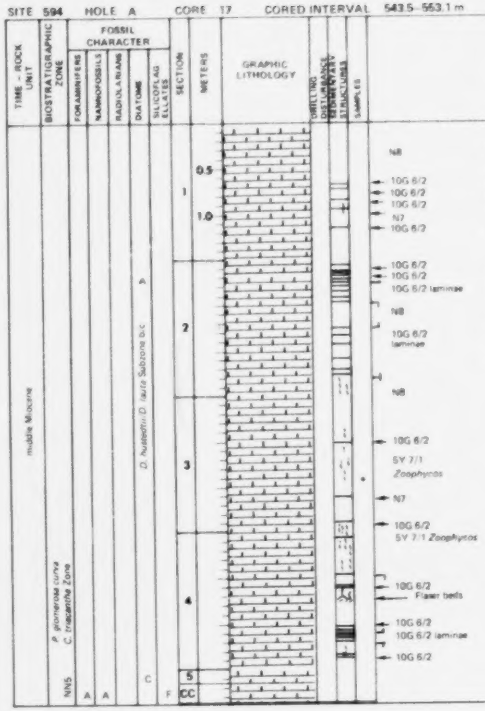
NANNOFOSSIL CHALK, very light gray (N8), numerous pale green laminae (10G 6/2 to 10G 8/2) and thin (<2 mm) medium light gray (N6) laminae. Burrows common.

SPONGE SPICULE-BEARING CLAYEY NANNOFOSSIL CHALK, olive gray to brown (5Y 4/2), very hard (porcelanitic) with *Chondrites* burrows. Layer continues into top 10 cm of Section 6. Probable turbidite.

SMEAR SLIDE SUMMARY

	4, 75	5, 141	6, 7
	D	M	M
Composition:			
Quartz	–	T	R
Feldspar	T	–	–
Heavy minerals	–	–	R
Volcanic glass	T	C	–
Clay minerals	–	C	C
Mica	T	T	C
Pyrite	T	T	R
Foraminifers	R	R	R
Calc. nannofossils	D	A	A
Diatoms	T	–	R
Sponge spicules	R	T	C

SITE 594 HOLE A CORE 17 CORED INTERVAL 543.5–553.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SILICOFLAGELLATES
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva
C. triacantha Zone
NN5
D. hustedtii/D. lauta Subzone b/c
A
A
A
C
F
0.5
1.0
1
2
3
4
5
CC
N8
10G 6/2
10G 6/2
10G 6/2
N7
10G 6/2
10G 6/2
10G 6/2
10G 6/2 laminae
N8
10G 6/2 laminae
N8
10G 6/2
5Y 7/1
Zoophycos
N7
10G 6/2
5Y 7/1 Zoophycos
10G 6/2
Flaser beds
10G 6/2
10G 6/2 laminae
10G 6/2

LITHOLOGIC DESCRIPTION

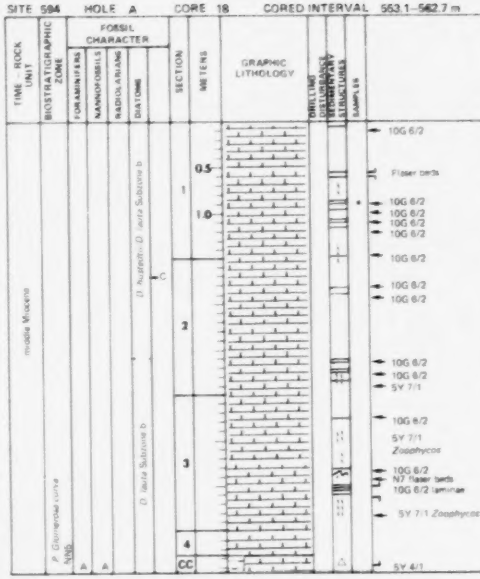
ENTIRE CORE BROKEN INTO BISCUITS BY CORING.

NANNOFOSSIL CHALK, white (N8 to N9) with abundant pale green (10G 6/2), thin (<2 mm) laminae. Almost all burrows gray (N4). Some sulfide stains. Flaser beds in Section 4.

SMEAR SLIDE SUMMARY

	3, 95
	D
Composition	
Quartz	T
Mica	T
Pyrite	T
Foraminifers	C
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

SITE 594 HOLE A CORE 18 CORED INTERVAL 553.1–562.7 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. Glomerosa curva
NN6
D. hustedtii–D. lauta Subzone b
D. lauta Subzone b
C
A
A
0.5
1.0
1
2
3
4
CC
10G 6/2
Flaser beds
10G 6/2
10G 6/2
10G 6/2
10G 6/2
10G 6/2
10G 6/2
10G 6/2
10G 6/2
10G 6/2
5Y 7/1
10G 6/2
5Y 7/1
Zoophycos
10G 6/2
N7 flaser beds
10G 6/2 laminae
5Y 7/1 Zoophycos
5Y 4/1

LITHOLOGIC DESCRIPTION

ENTIRE CORE BROKEN INTO BISCUITS BY CORING.

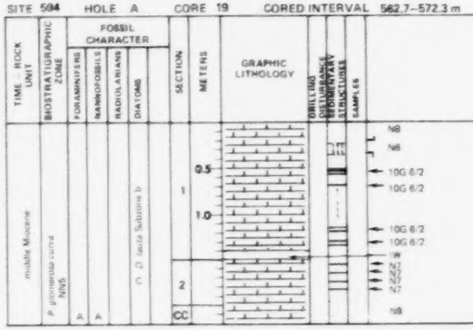
NANNOFOSSIL CHALK, white (N8) with abundant pale green (10G 6/2) laminae. Burrowing. *Chondrites* and *Zoophycos* abundant. Flaser beds occur in Sections 1 and 3.

Core catcher has layer of SPICULE-BEARING RECRYSTALLIZED NANNOFOSSIL CHALK, olive gray brown (5Y 4/1), probable turbidite.

SMEAR SLIDE SUMMARY

	1, 90
	D
Composition	
Mica	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Diatoms	T
Sponge spicules	R

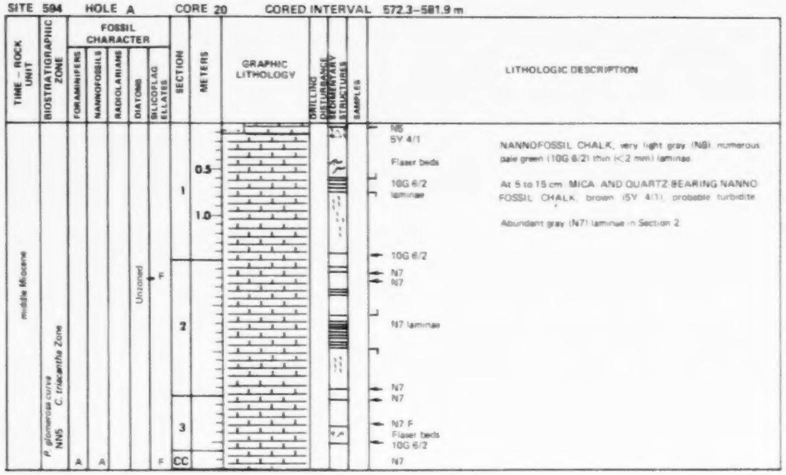
SITE 594 HOLE A CORE 19 CORED INTERVAL 562.7–572.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curva
NN5
C. D. lauta Subzone b
A
A
0.5
1.0
1
2
CC
N8
N6
10G 6/2
10G 6/2
10G 6/2
10G 6/2
N7
N7
N7
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), with gray sulfide-rich burrows and green (10G 6/2), thin (<2 mm) laminae.

SITE 594 HOLE A CORE 20 CORED INTERVAL 572.3–581.9 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SILICOFLAG ELLATES
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
middle Miocene
P. glomerosa curve
NN5 C. triacantha Zone
A
A
Unzoned
F
F
1
2
3
CC
0.5
1.0
N6
5Y 4/1
Flaser beds
10G 6/2
laminae
10G 6/2
N7
N7
N7 laminae
N7
N7
N7 F
Flaser beds
10G 6/2
N7

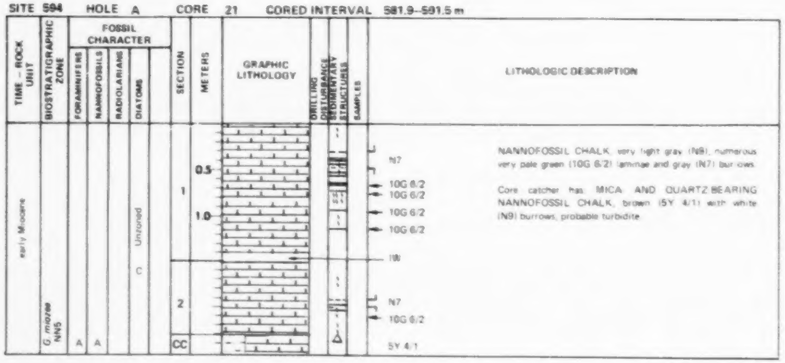
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), numerous pale green (10G 6/2) thin (<2 mm) laminae.

At 5 to 15 cm MICA AND QUARTZ-BEARING NANNOFOSSIL CHALK, brown (5Y 4/1), probable turbidite.

Abundant gray (N7) laminae in Section 2.

SITE 594 HOLE A CORE 21 CORED INTERVAL 581.9–591.5 m

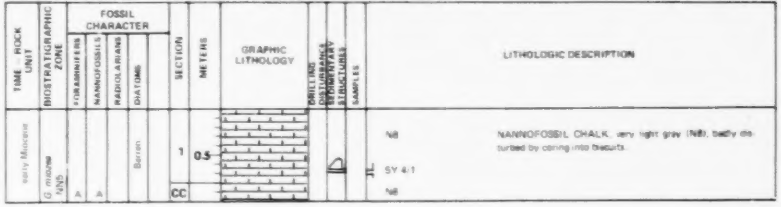

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Unzoned
C
1
2
CC
0.5
1.0
N7
10G 6/2
10G 6/2
10G 6/2
10G 6/2
N9
N7
10G 6/2
5Y 4/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), numerous very pale green (10G 6/2) laminae and gray (N7) burrows.

Core catcher has MICA AND QUARTZ-BEARING NANNOFOSSIL CHALK, brown (5Y 4/1) with white (N9) burrows, probable turbidite.

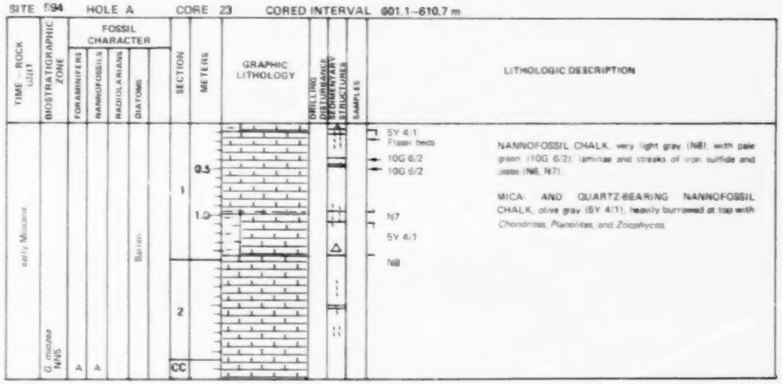
SITE 594 HOLE A CORE 22 CORED INTERVAL 591.5–601.1 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Barren
1
CC
0.5
N8
5Y 4/1
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), badly disturbed by coring into biscuits.

SITE 594 HOLE A CORE 23 CORED INTERVAL 601.1–610.7 m

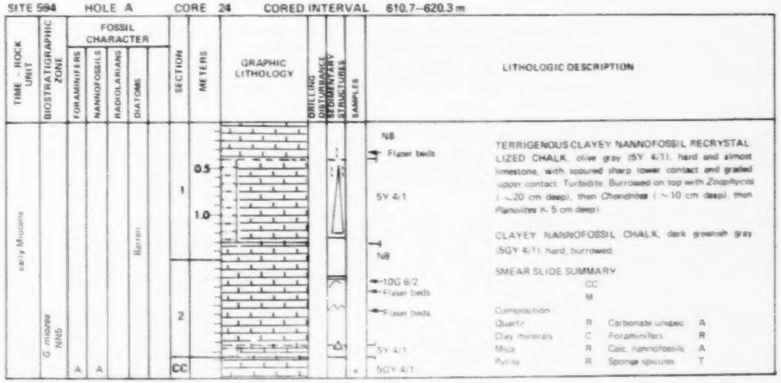

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Barren
1
2
CC
0.5
1.0
5Y 4/1
Flaser beds
10G 6/2
10G 6/2
N7
5Y 4/1
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8), with pale green (10G 6/2) laminae and streaks of iron sulfide and ooze (N6, N7).

MICA- AND QUARTZ-BEARING NANNOFOSSIL CHALK, olive gray (5Y 4/1), heavily burrowed at top with *Chondrites*, *Planolites*, and *Zoophycos*.

SITE 594 HOLE A CORE 24 CORED INTERVAL 610.7–620.3 m


TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Barren
1
2
CC
0.5
1.0
N8
Flaser beds
5Y 4/1
N8
10G 6/2
Flaser beds
Flaser beds
5Y 4/1
5GY 4/1

LITHOLOGIC DESCRIPTION

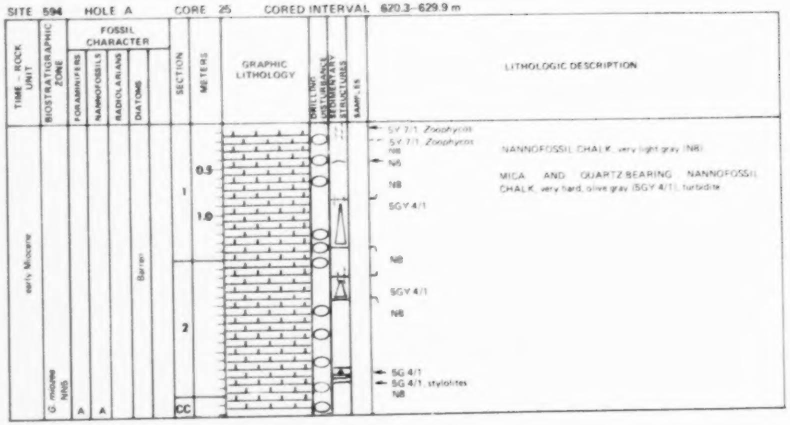
TERRIGENOUS CLAYEY NANNOFOSSIL RECRYSTALLIZED CHALK, olive gray (5Y 4/1), hard and almost limestone, with scoured sharp lower contact and graded upper contact. Turbidite. Burrowed on top with *Zoophycos* (~20 cm deep), then *Chondrites* (~10 cm deep), then *Planolites* (< 5 cm deep).

CLAYEY NANNOFOSSIL CHALK, dark greenish gray (5GY 4/1), hard, burrowed.

SMEAR SLIDE SUMMARY

	CC M		
Composition			
Quartz	R	Carbonate unspec.	A
Clay minerals	C	Foraminifers	R
Mica	R	Calc. nannofossils	A
Pyrite	R	Sponge spicules	T

SITE 594 HOLE A CORE 25 CORED INTERVAL 620.3–629.9 m

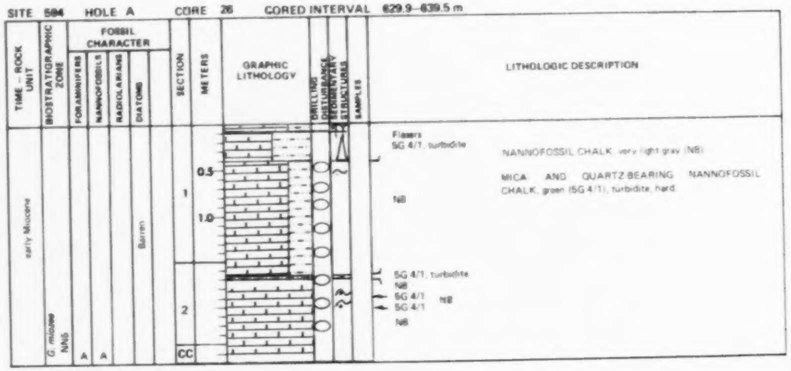

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Barren
1
2
CC
0.5
1.0
5Y 7/1, Zoophycos
5Y 7/1, Zoophycos
N8
N8
N8
5GY 4/1
N8
5GY 4/1
N8
5G 4/1
5G 4/1, stylolites
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very light gray (N8)

MICA AND QUARTZ-BEARING NANNOFOSSIL CHALK, very hard, olive gray (5GY 4/1), turbidite

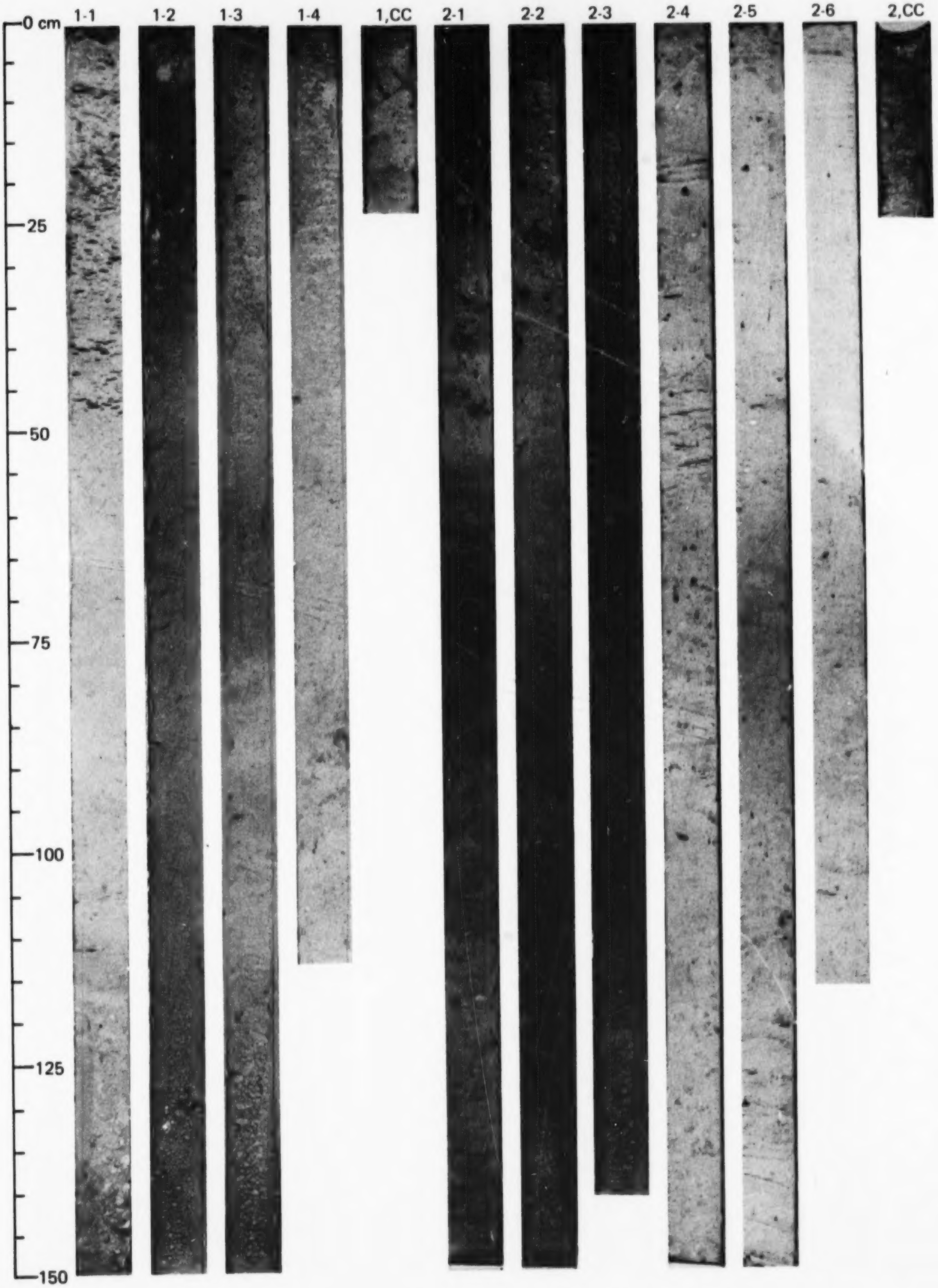
SITE 594 HOLE A CORE 26 CORED INTERVAL 629.9–639.5 m

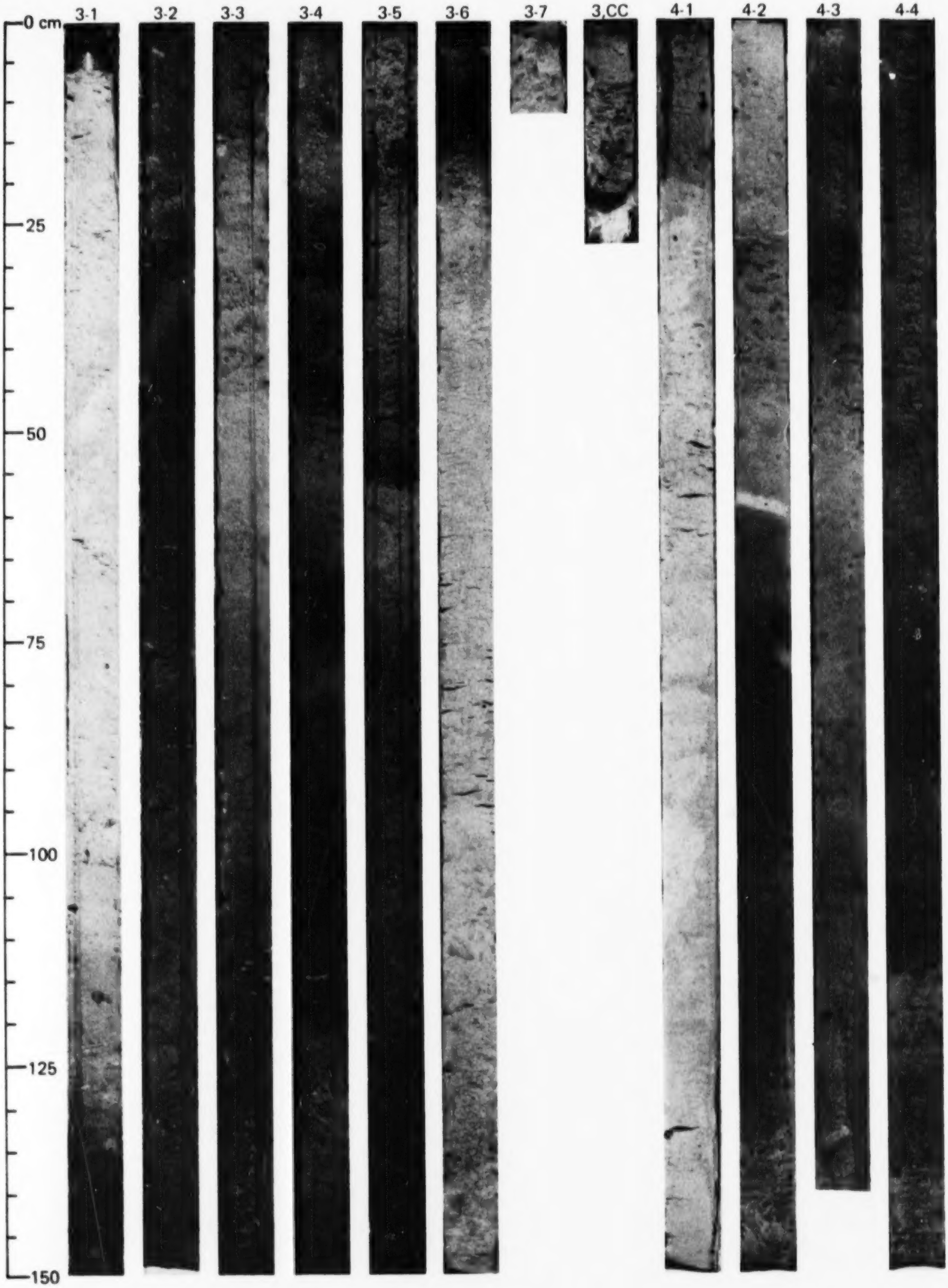

TIME – ROCK UNIT
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER
FORAMINIFERS
NANNOFOSSILS
RADIOLARIANS
DIATOMS
SECTION
METERS
GRAPHIC LITHOLOGY
DRILLING DISTURBANCE
SEDIMENTARY STRUCTURES
SAMPLES
early Miocene
G. miozea
NN5
A
A
Barren
1
2
CC
0.5
1.0
Flasers
5G 4/1, turbidite
N8
5G 4/1, turbidite
N8
5G 4/1
5G 4/1
N8
N8

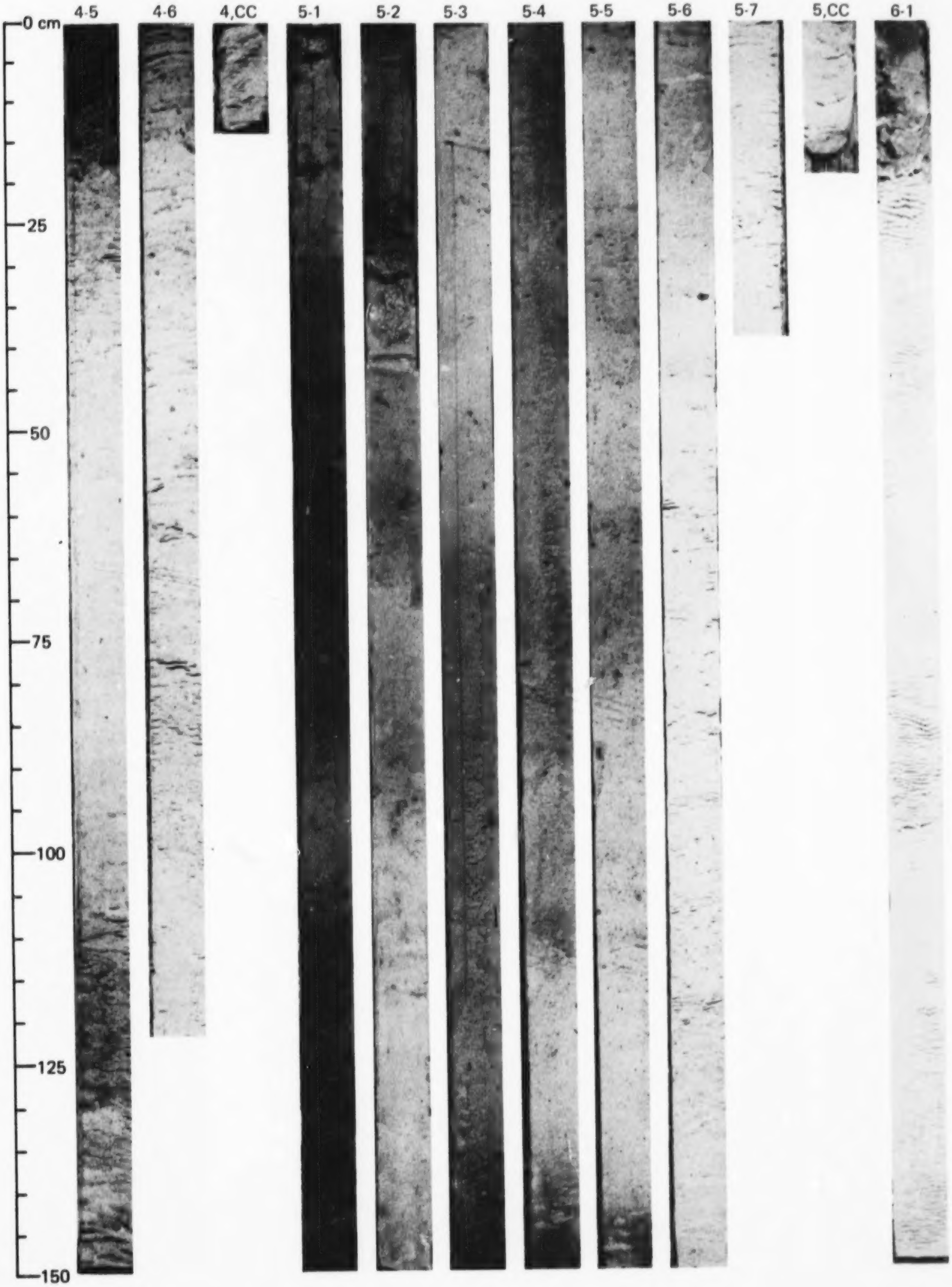
LITHOLOGIC DESCRIPTION

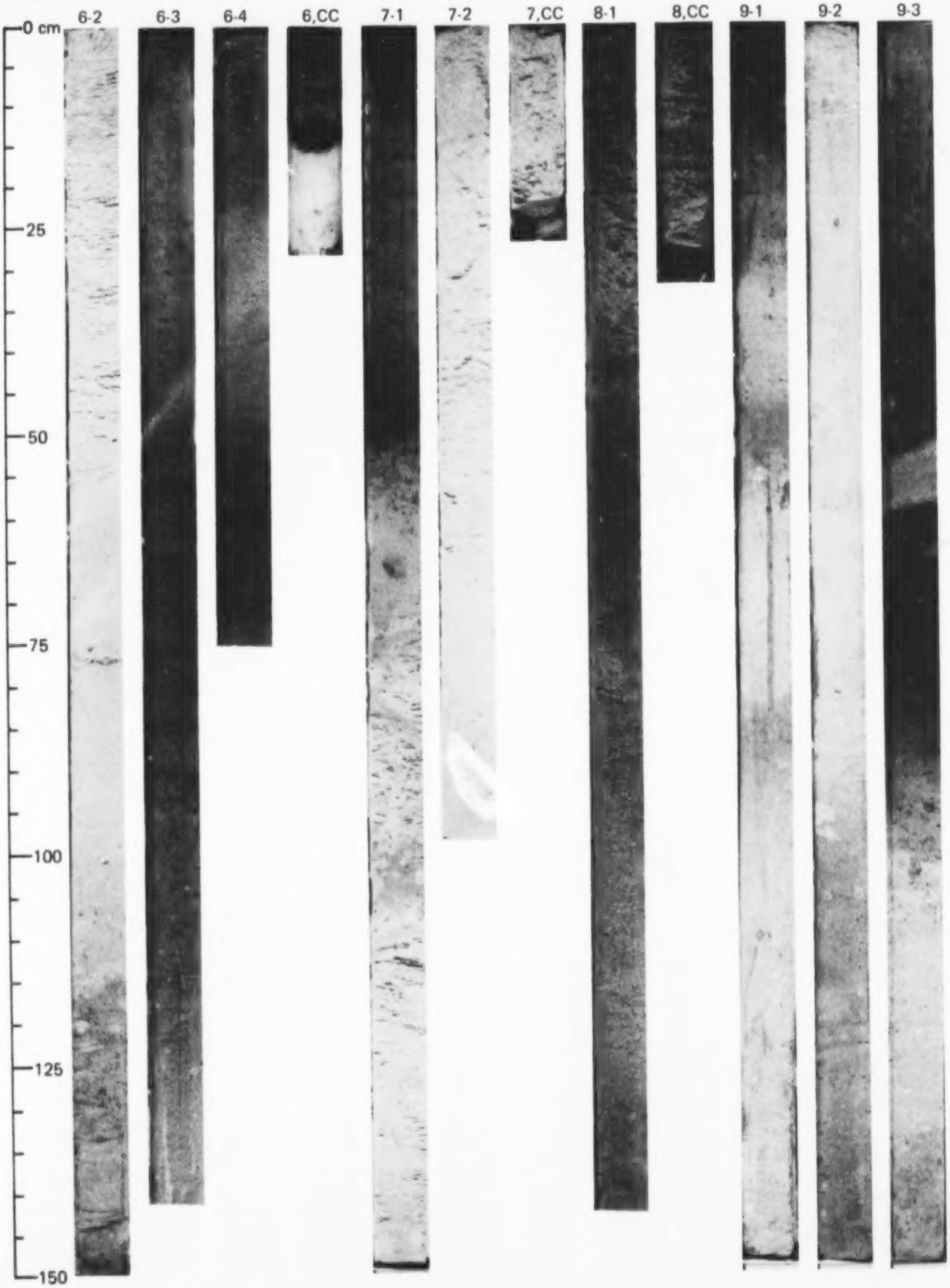
NANNOFOSSIL CHALK, very light gray (N8)

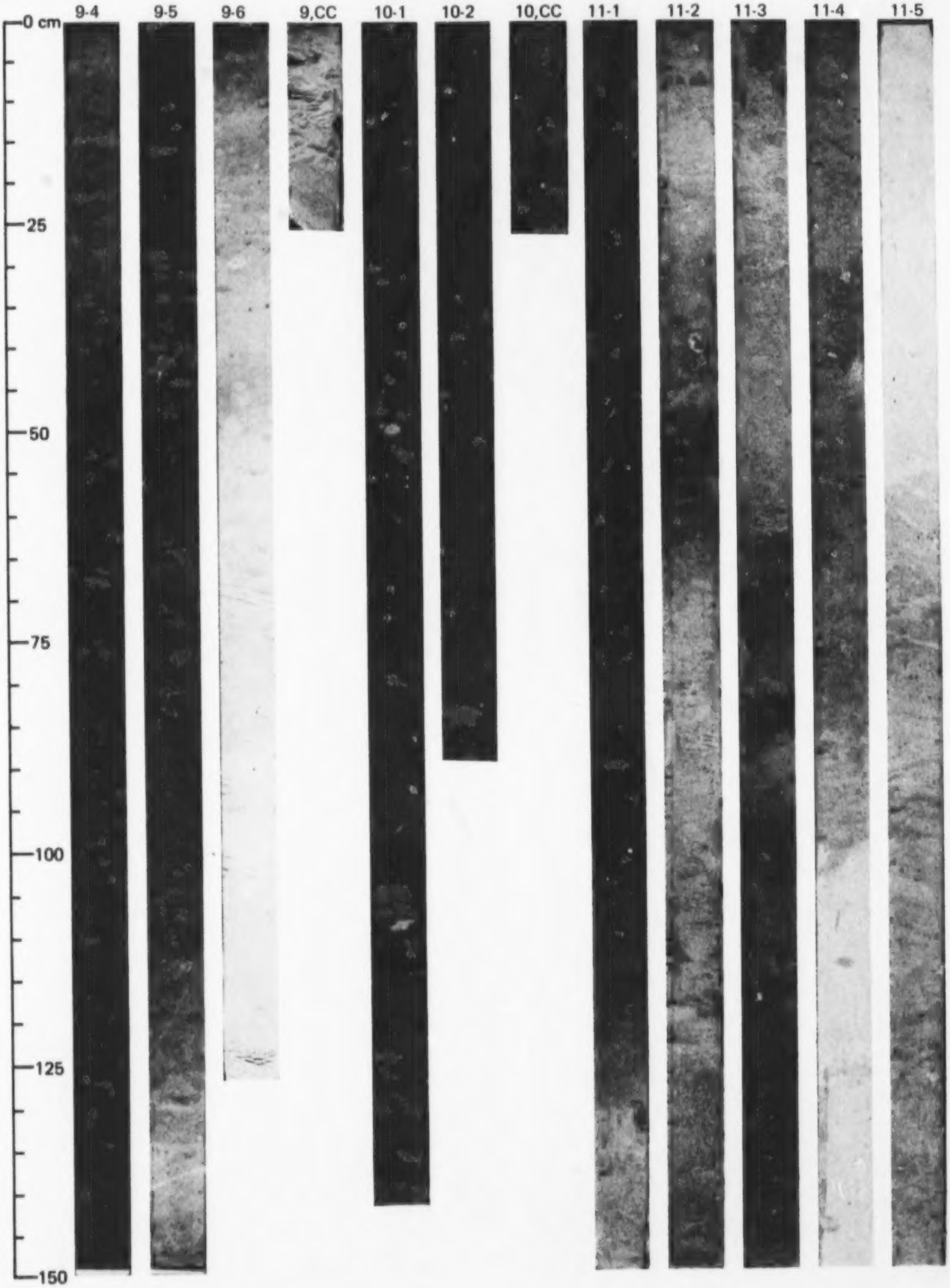
MICA AND QUARTZ-BEARING NANNOFOSSIL CHALK, green (5G 4/1), turbidite, hard

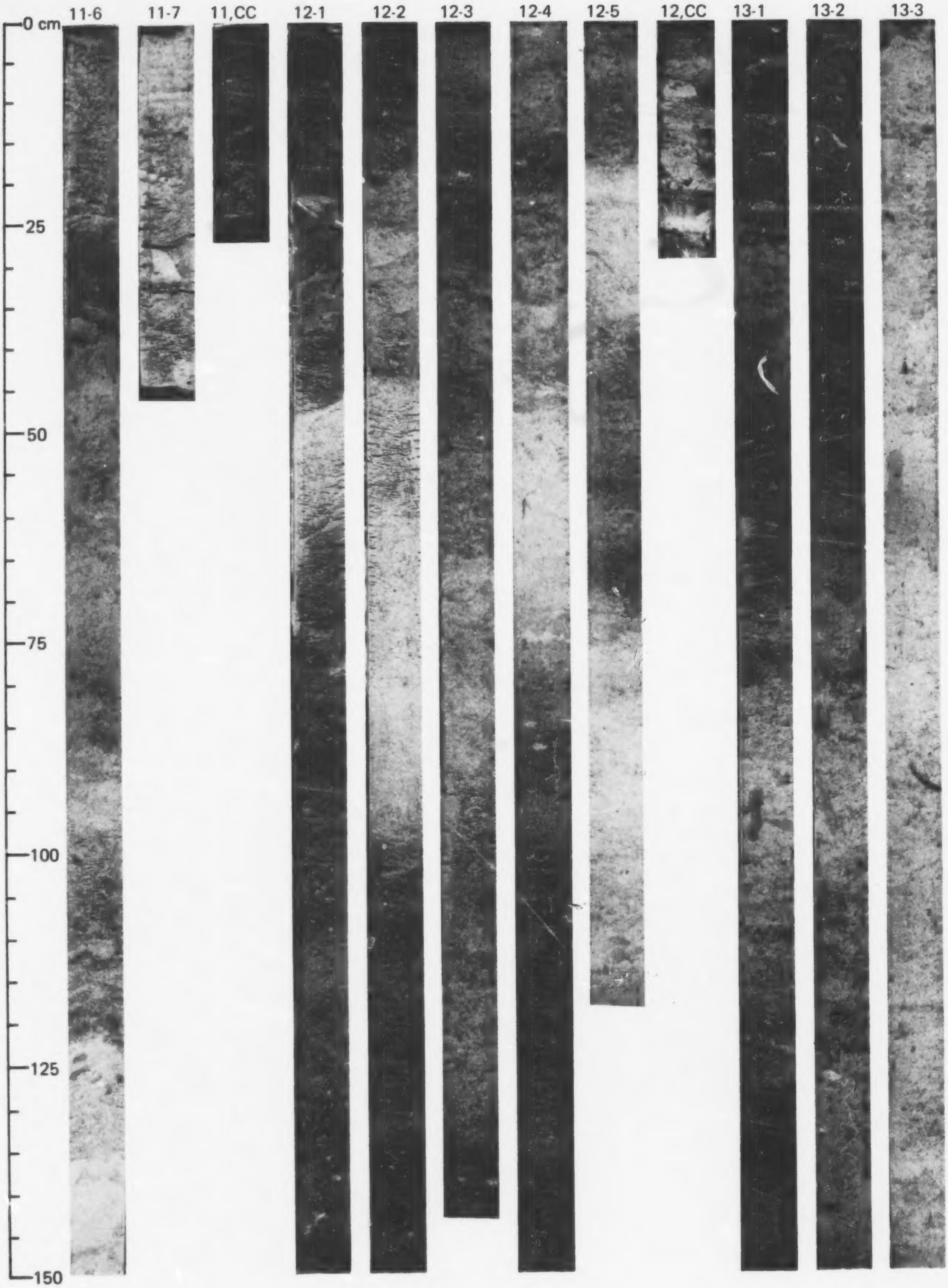

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2,CC

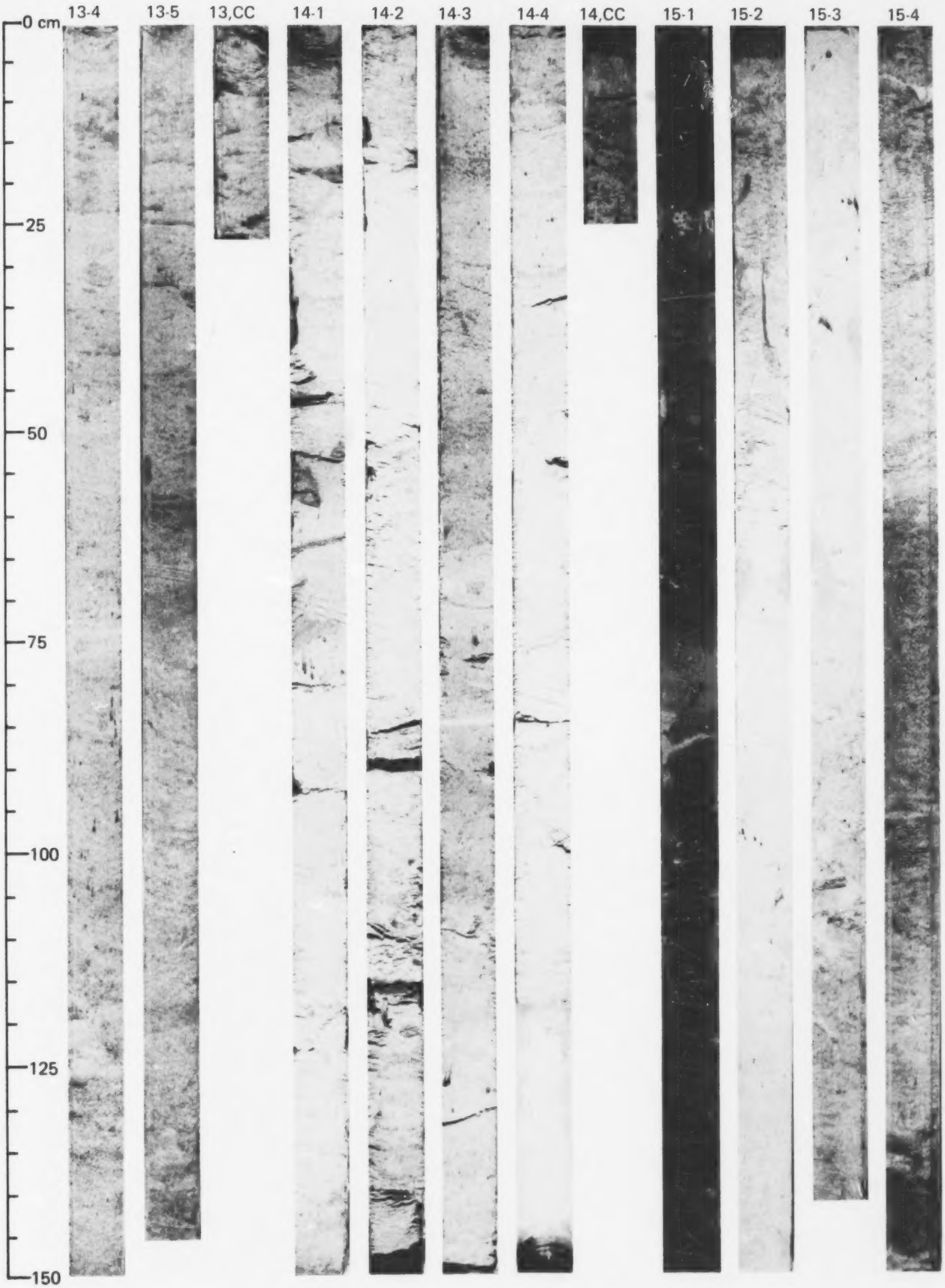

0 cm
25
50
75
100
125
150
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3,CC
4-1
4-2
4-3
4-4

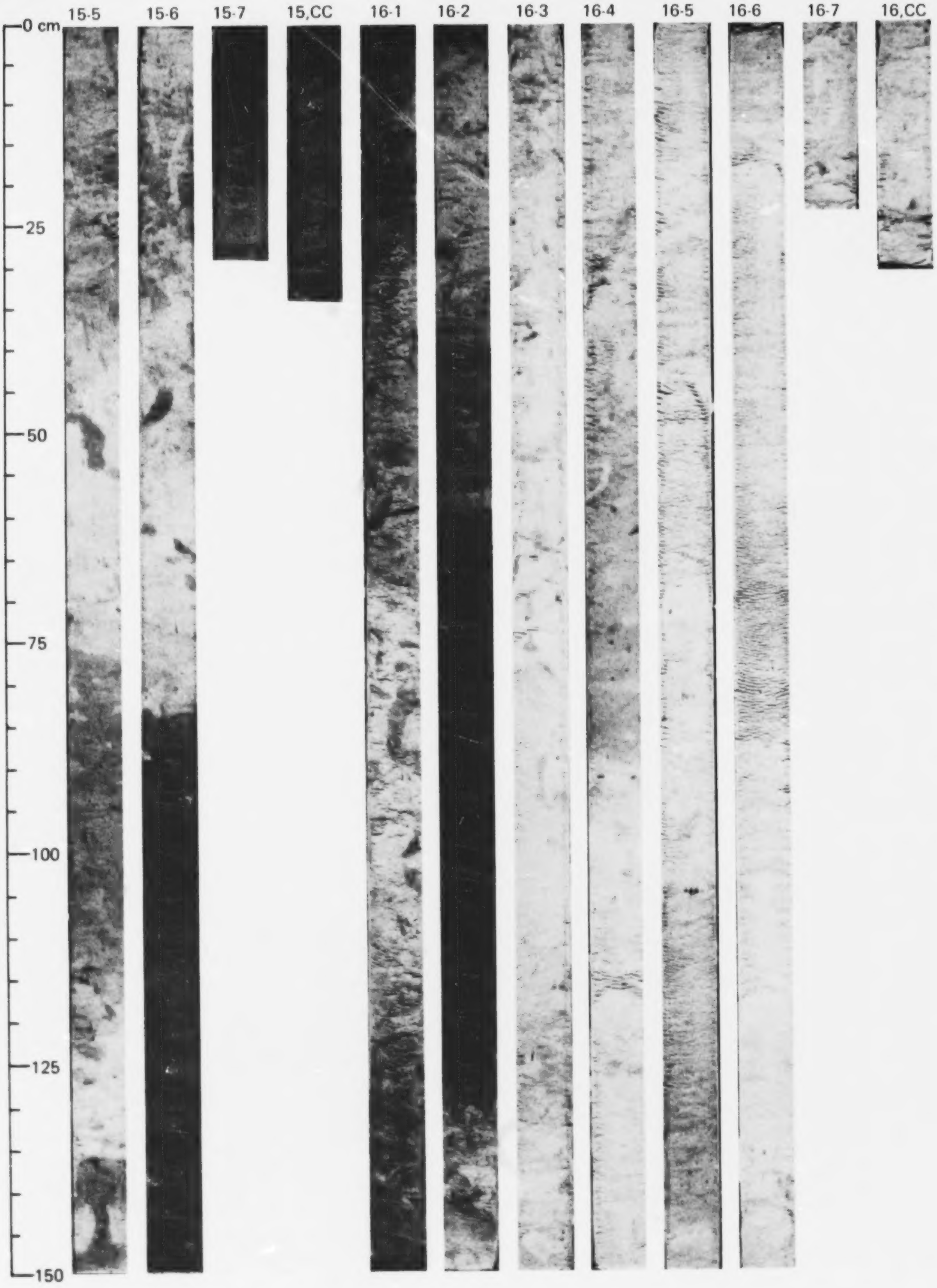

0 cm
25
50
75
100
125
150
4-5
4-6
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5,CC
6-1

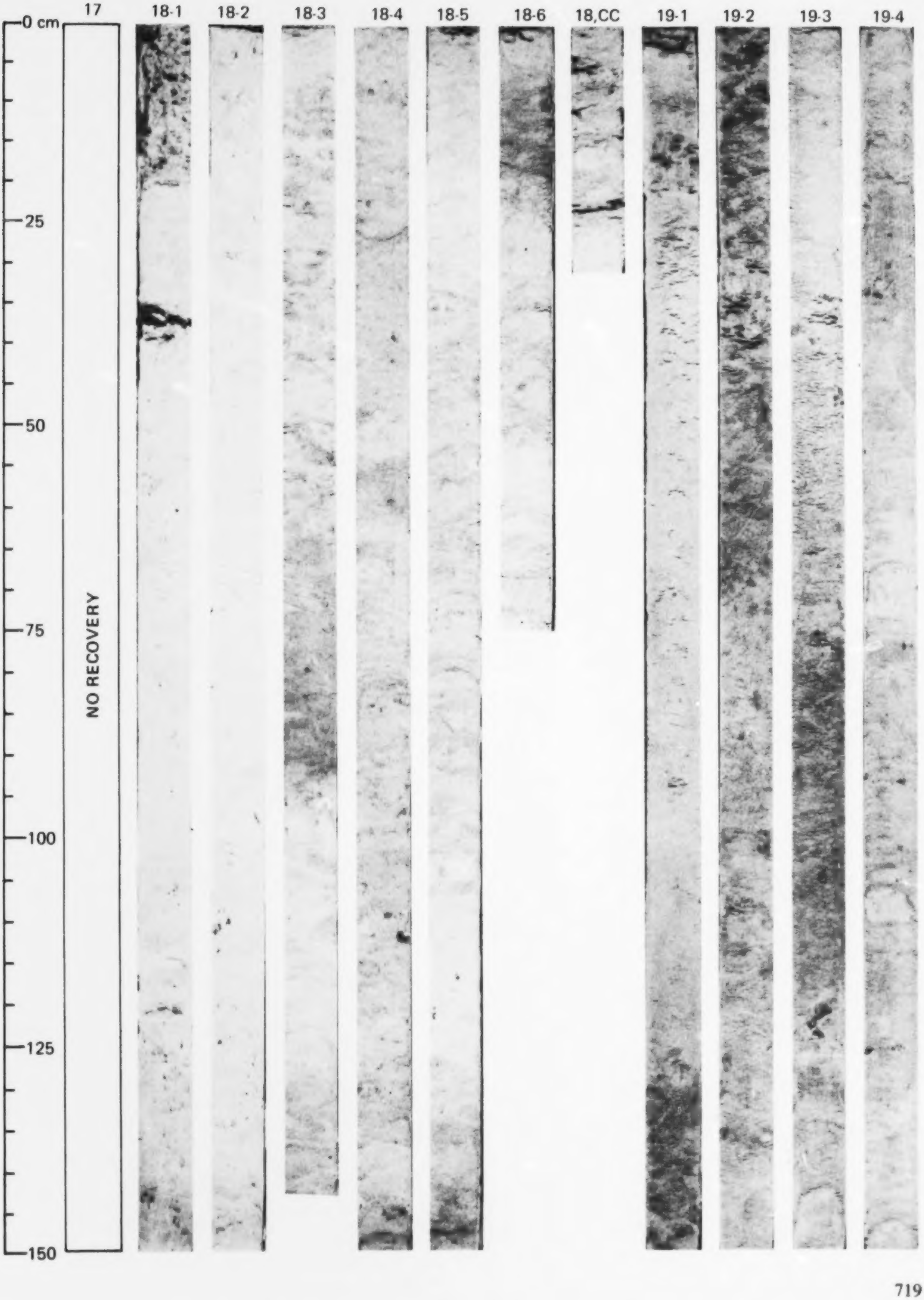

6-2
6-3
6-4
6,CC
7-1
7-2
7,CC
8-1
8,CC
9-1
9-2
9-3
0 cm
25
50
75
100
125
150

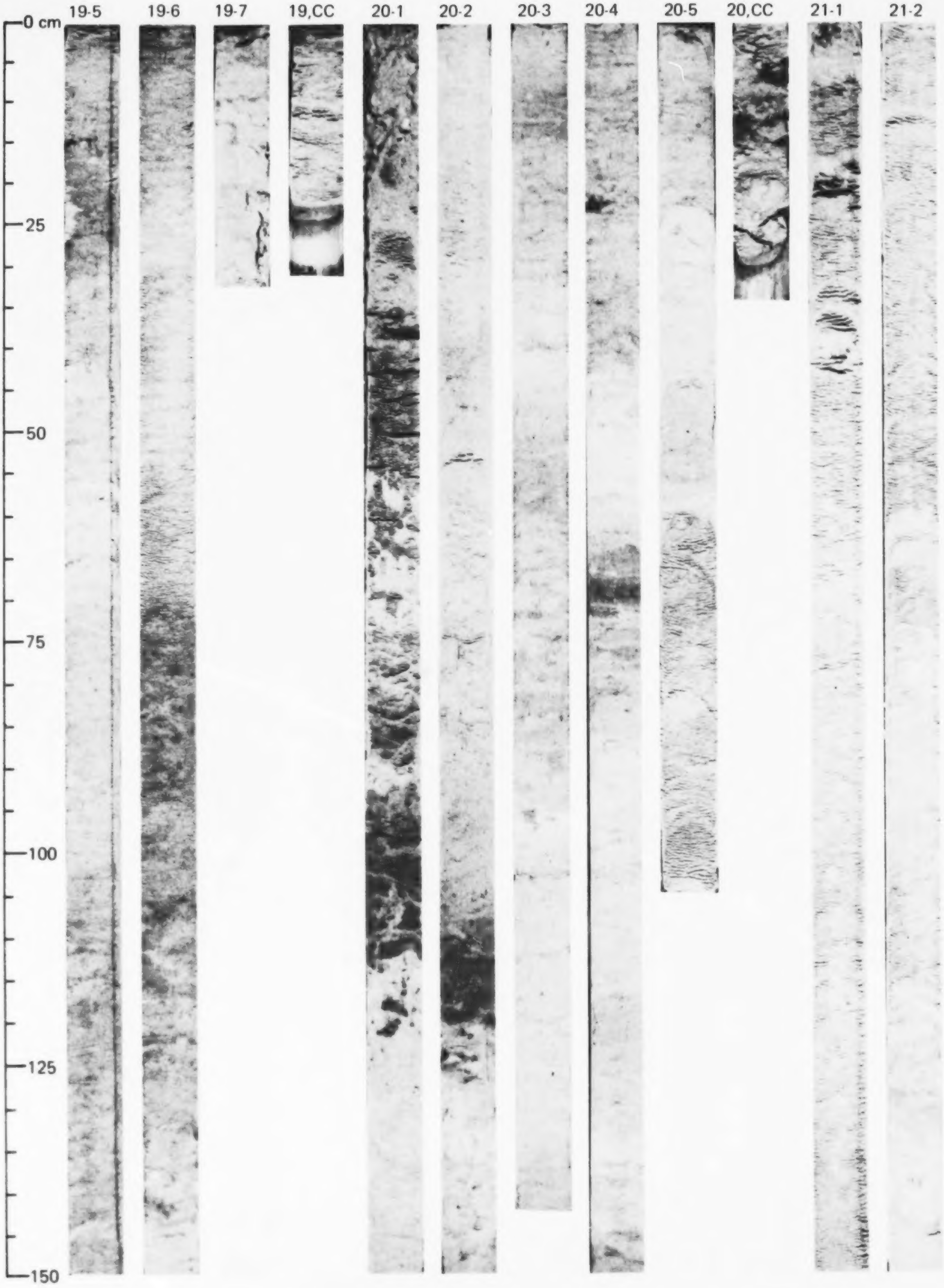

0 cm
25
50
75
100
125
150
9-4
9-5
9-6
9,CC
10-1
10-2
10,CC
11-1
11-2
11-3
11-4
11-5

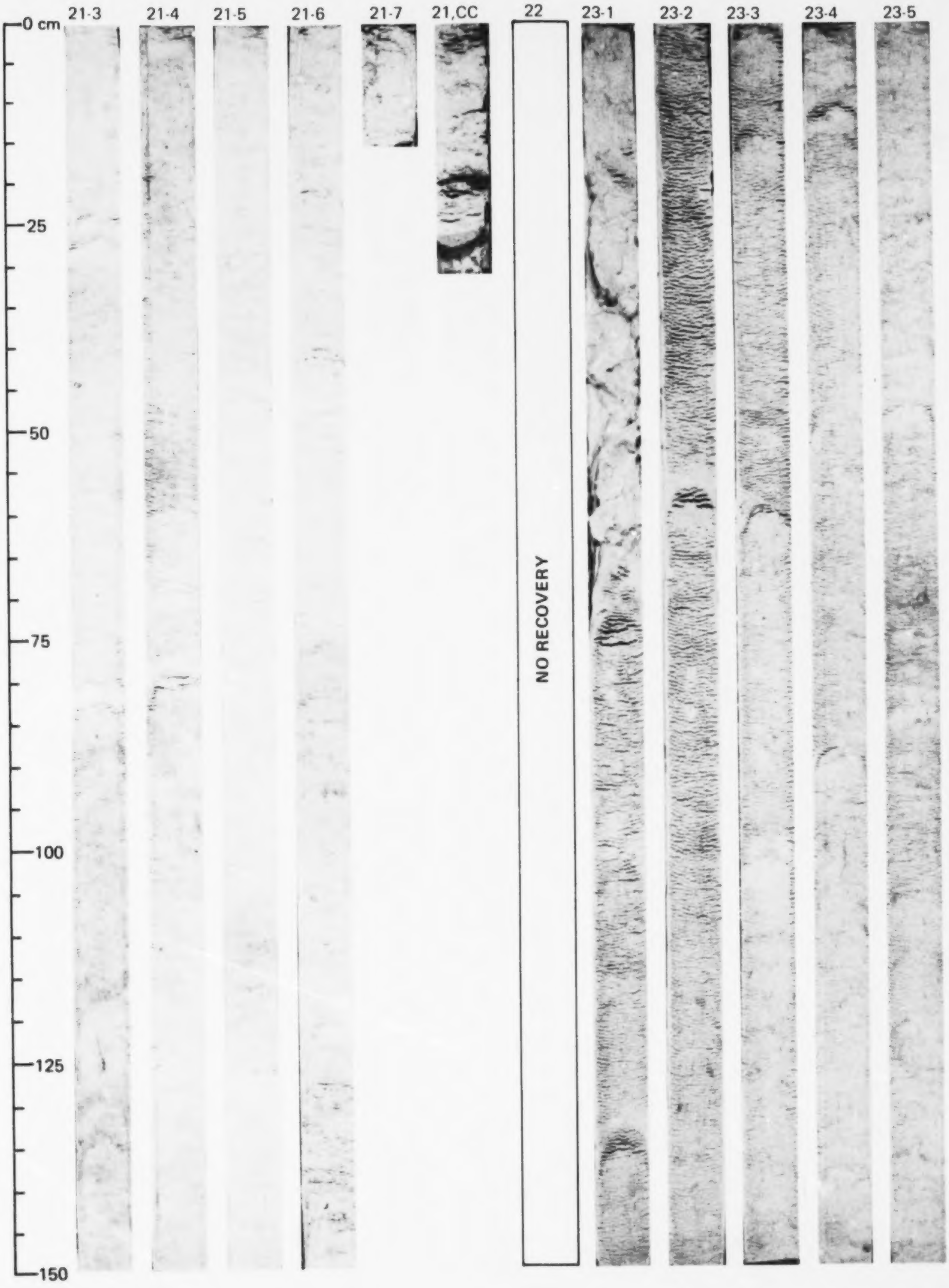

11-6
11-7
11,CC
12-1
12-2
12-3
12-4
12-5
12,CC
13-1
13-2
13-3
0 cm
25
50
75
100
125
150

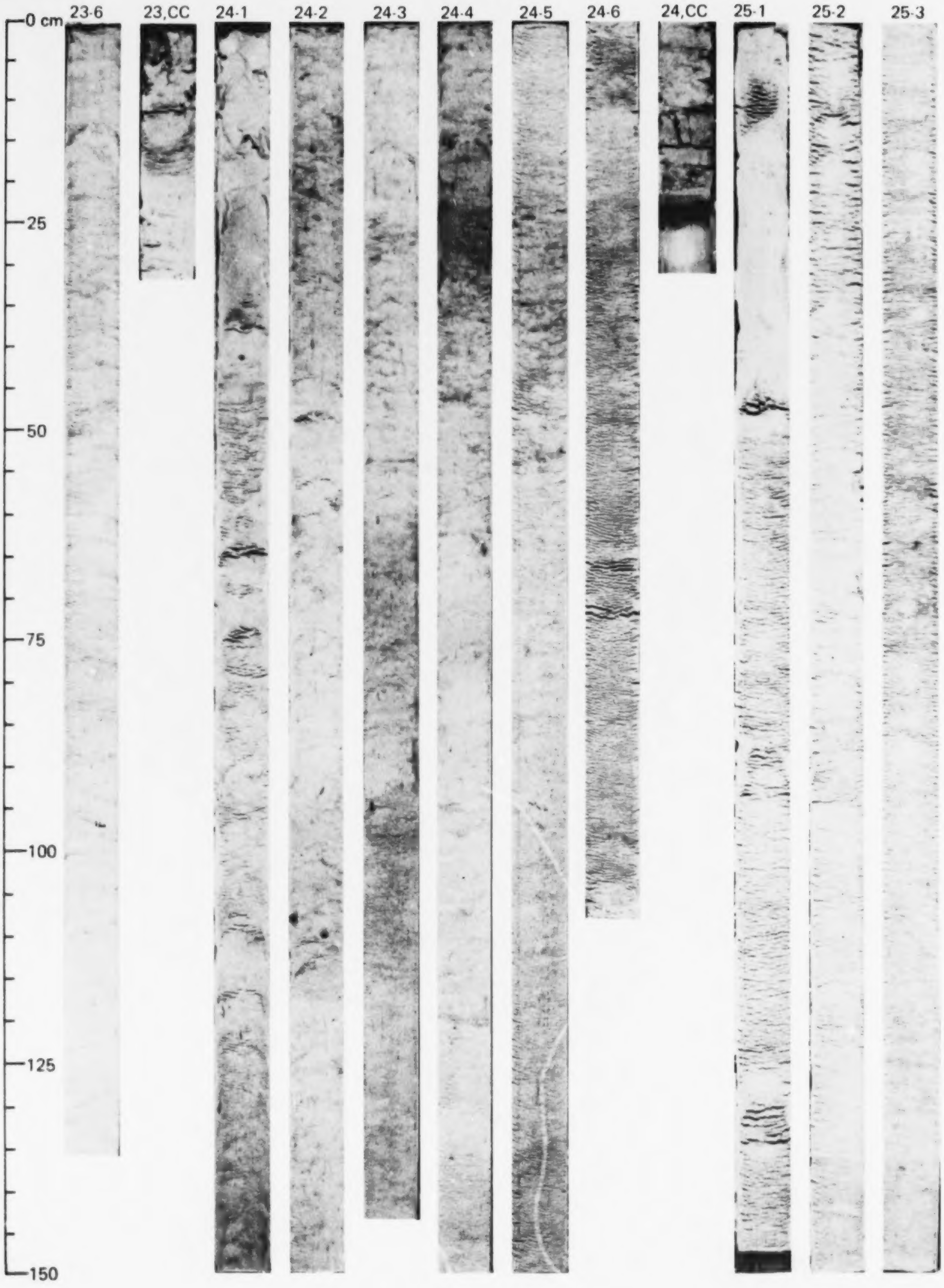

13-4
13-5
13,CC
14-1
14-2
14-3
14-4
14,CC
15-1
15-2
15-3
15-4
0 cm
25
50
75
100
125
150

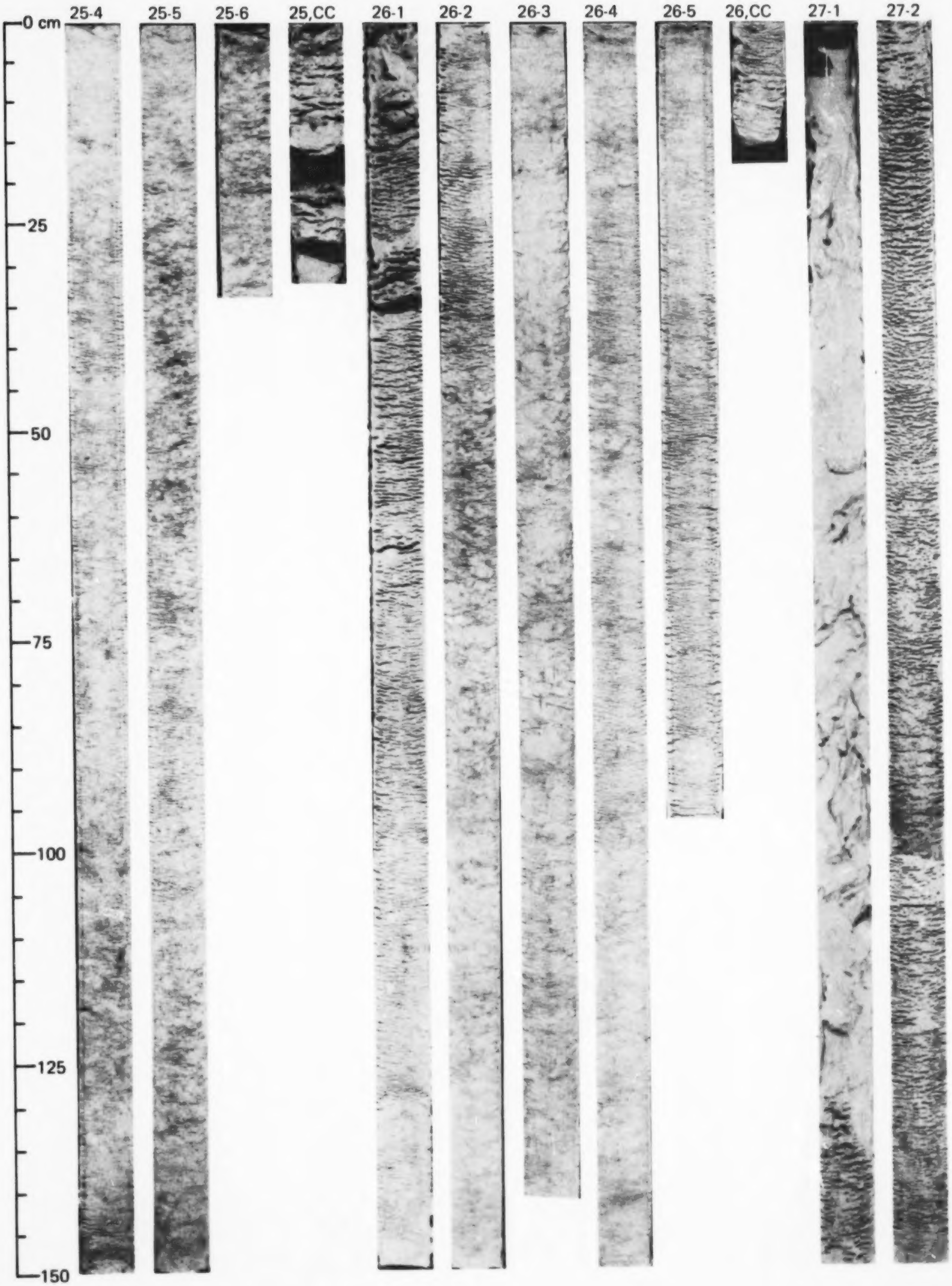

15-5
15-6
15-7
15,CC
16-1
16-2
16-3
16-4
16-5
16-6
16-7
16,CC
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
17
NO RECOVERY
18-1
18-2
18-3
18-4
18-5
18-6
18,CC
19-1
19-2
19-3
19-4


19-5
19-6
19-7
19,CC
20-1
20-2
20-3
20-4
20-5
20,CC
21-1
21-2
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
21-3
21-4
21-5
21-6
21-7
21,CC
22
NO RECOVERY
23-1
23-2
23-3
23-4
23-5


0 cm
25
50
75
100
125
150
23-6
23,CC
24-1
24-2
24-3
24-4
24-5
24-6
24,CC
25-1
25-2
25-3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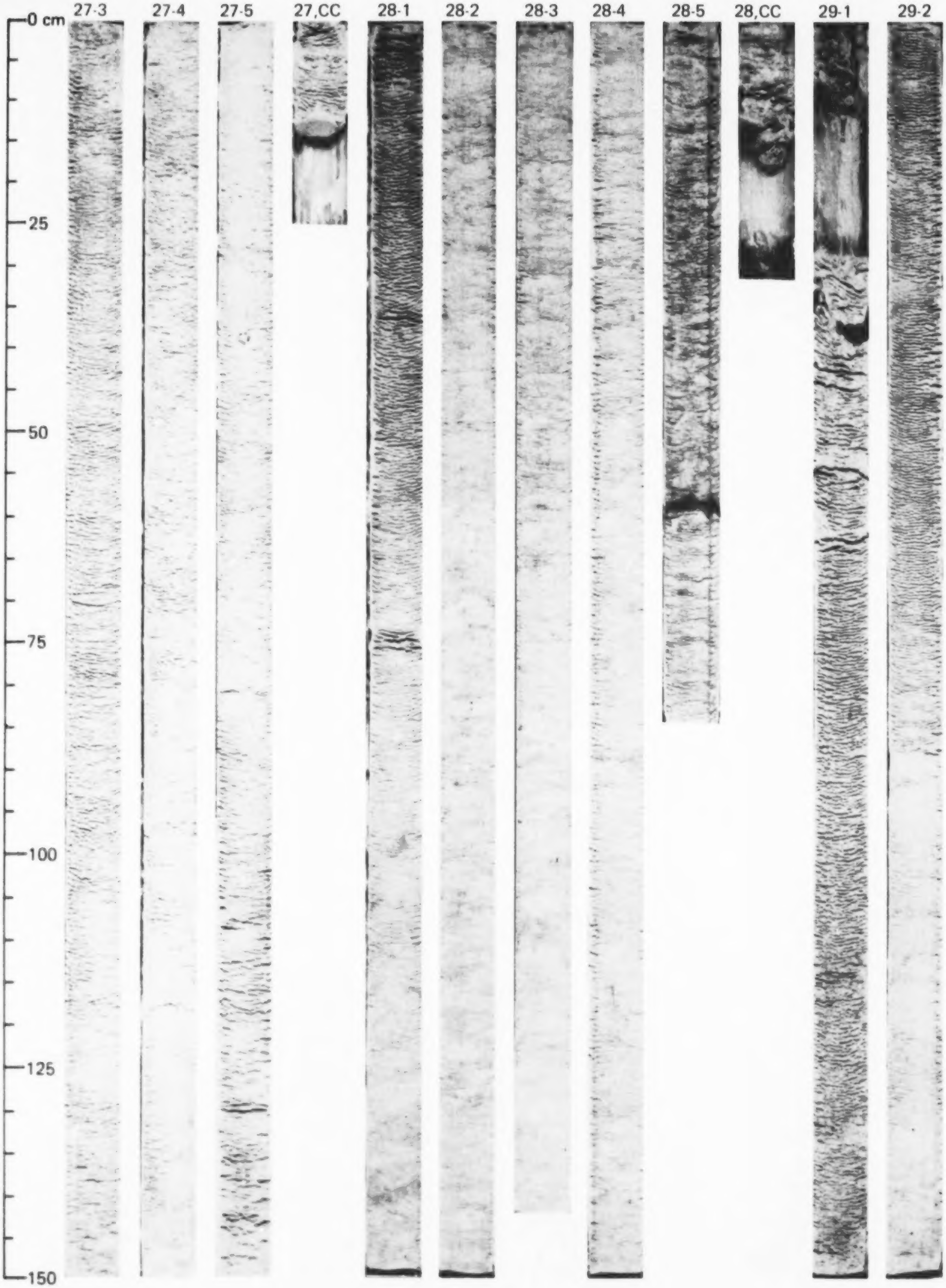
25-6
25,CC
26-1
26-2
26-3
26-4
26-5
26,CC
27-1
27-2


27-3
27-4
27-5
27,CC
28-1
28-2
28-3
28-4
28-5
28,CC
29-1
29-2
0 cm
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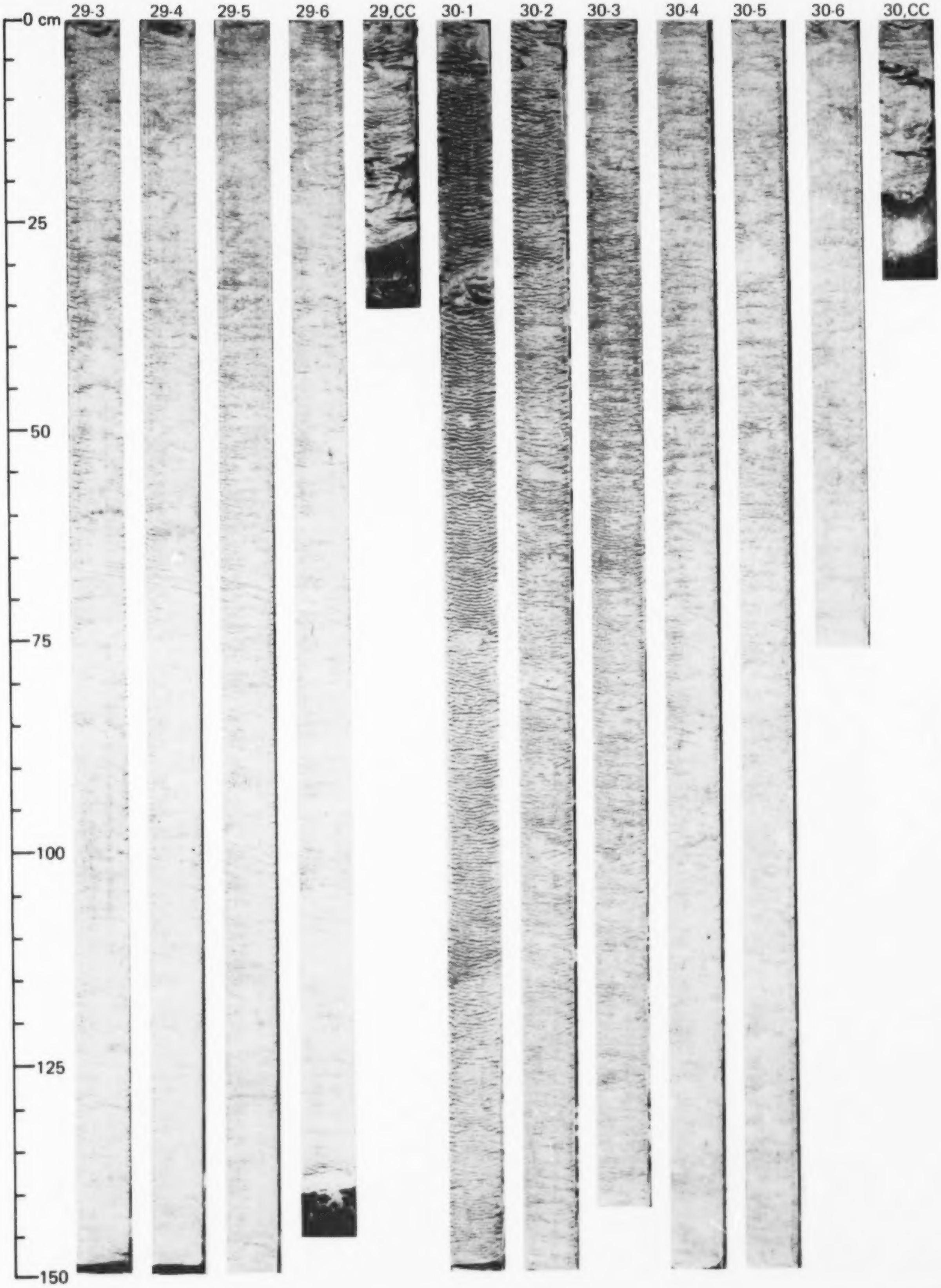
75
100
125
150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100
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29-5
29-6
29,CC
30-1
30-2
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30-4
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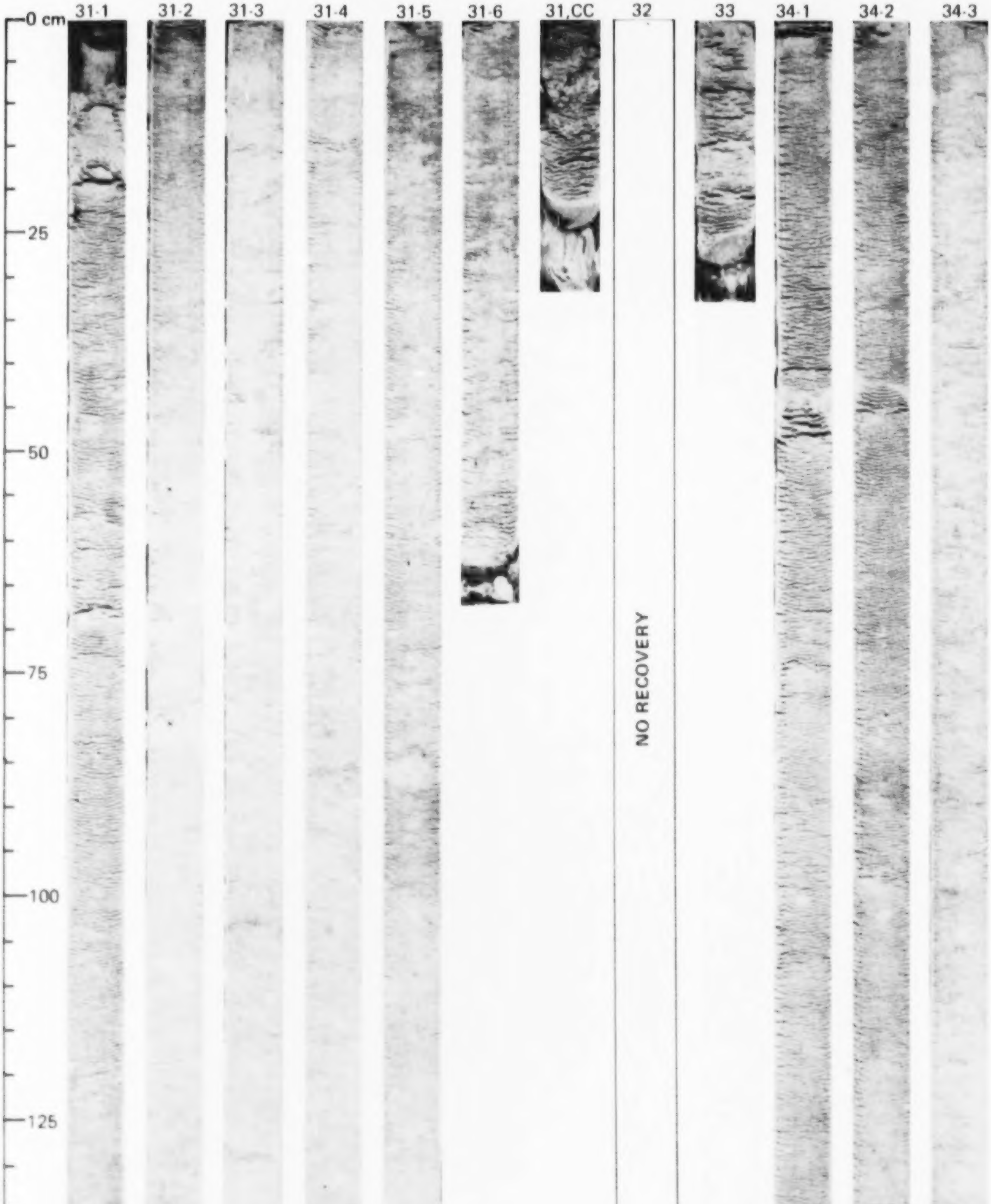
30-6
30,CC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31-4
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31-6
31,CC
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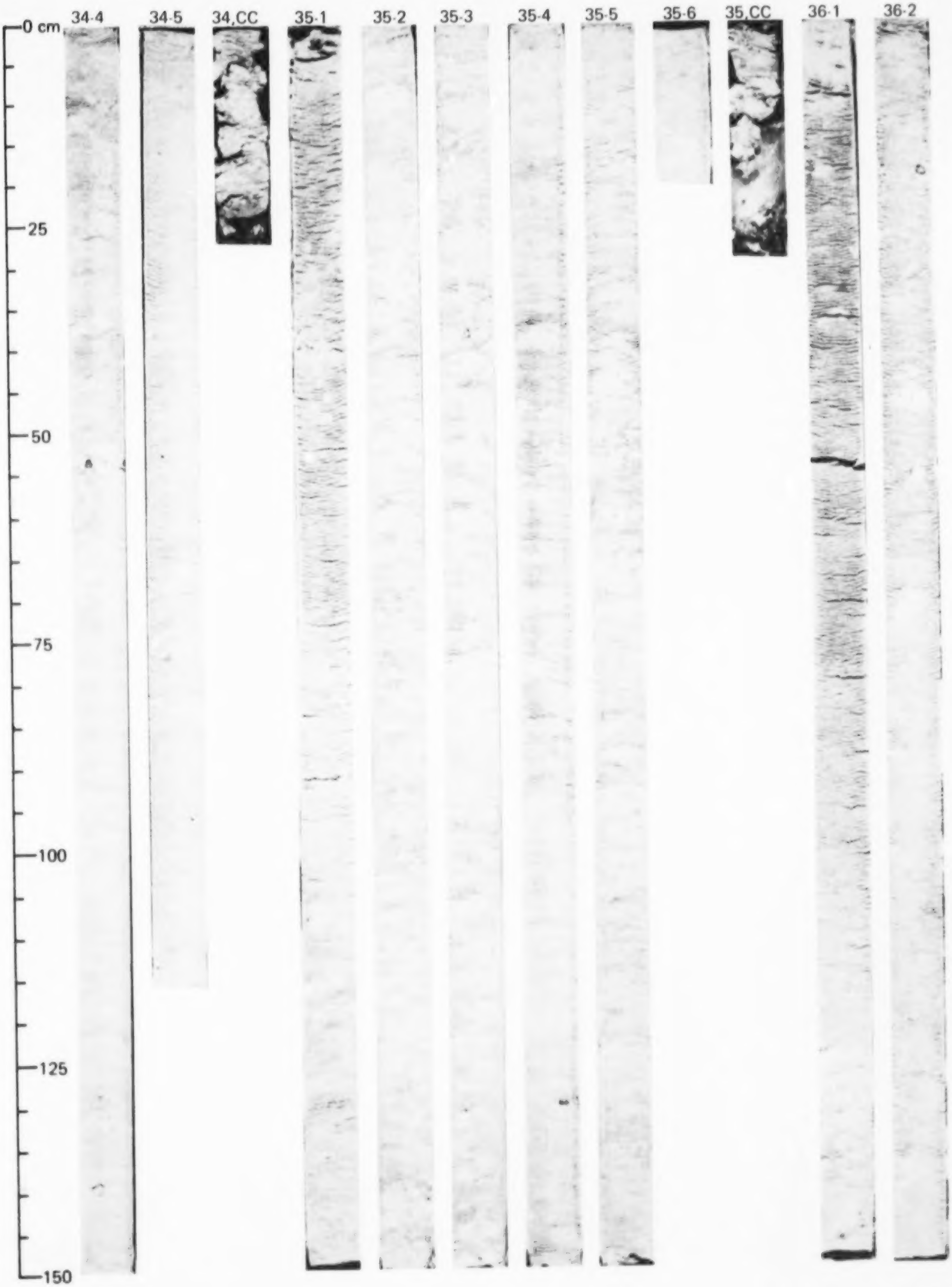
33
34-1
34-2
34-3
NO RECOVERY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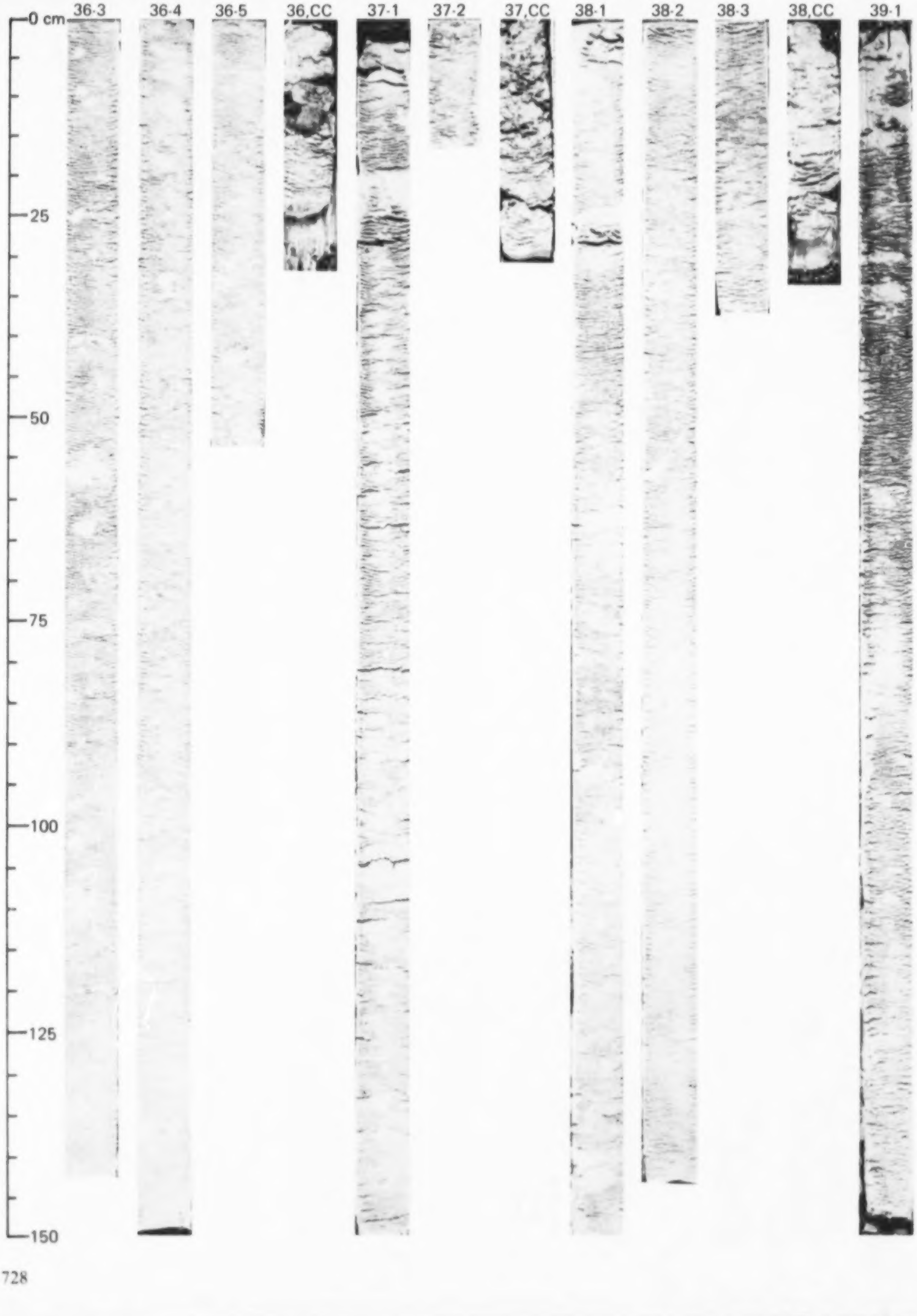
35-6
35,CC
36-1
36-2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37-2
37,CC
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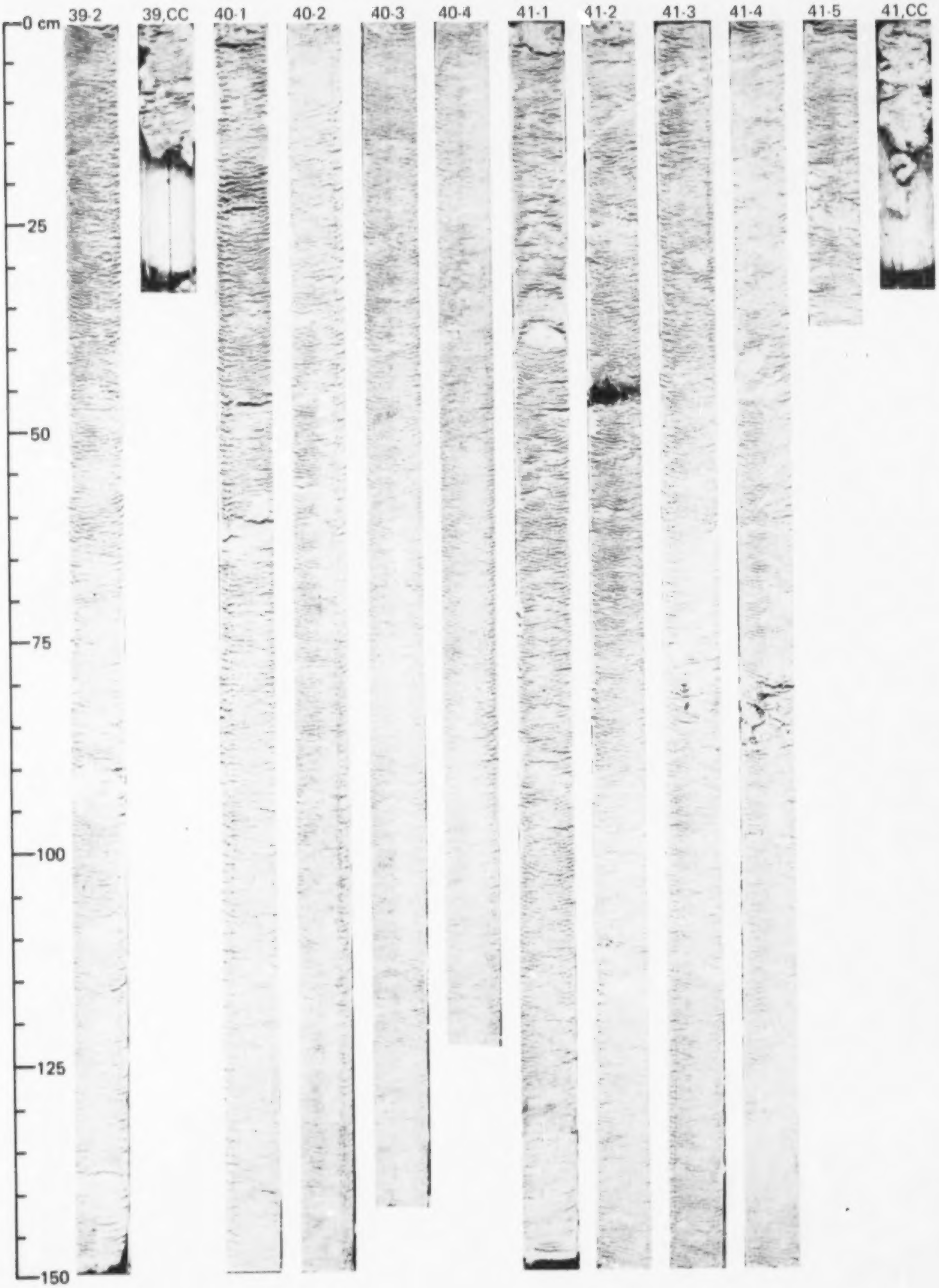
38-2
38-3
38,CC
39-1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39,CC
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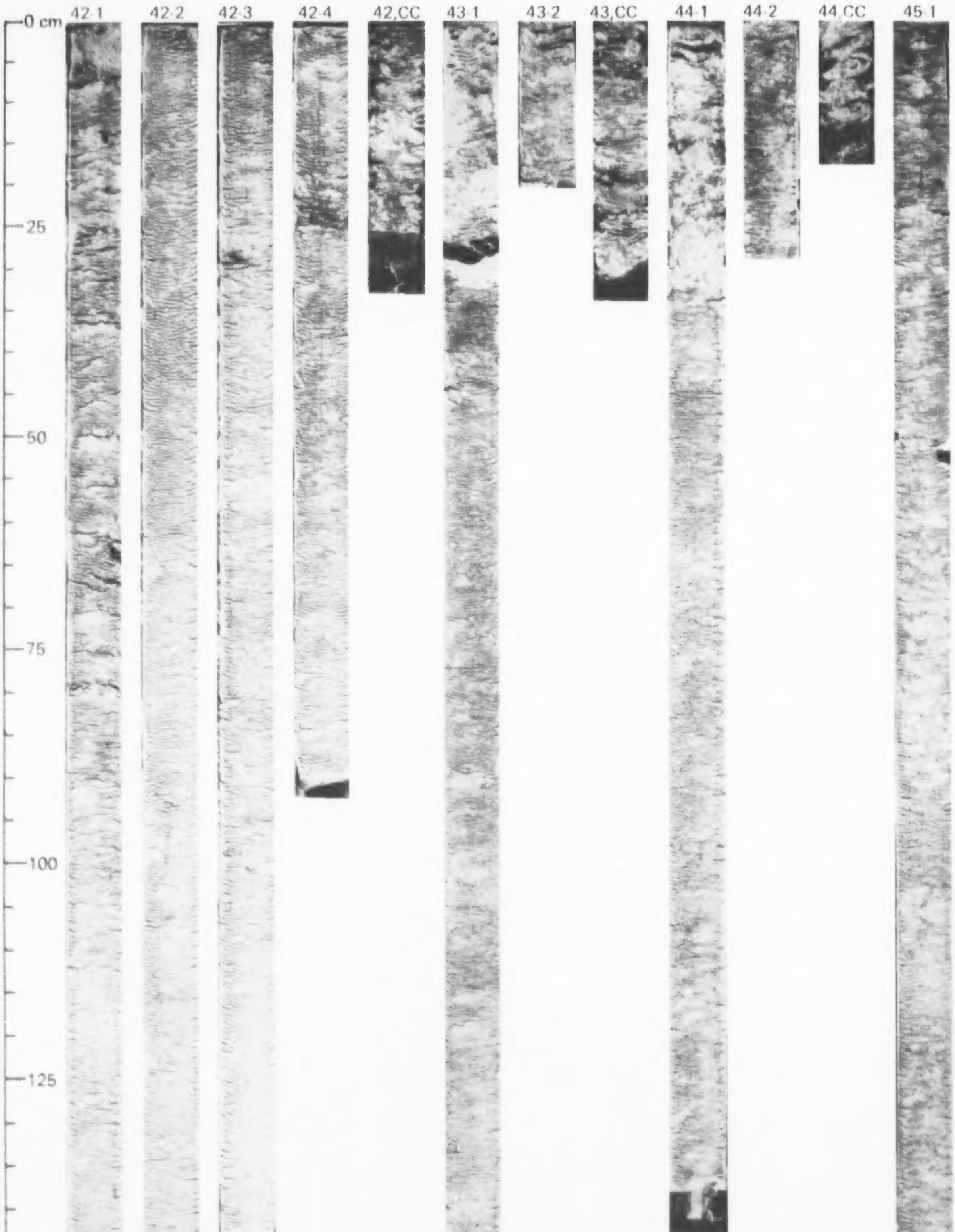
40-4
41-1
41-2
41-3
41-4
41-5
41,CC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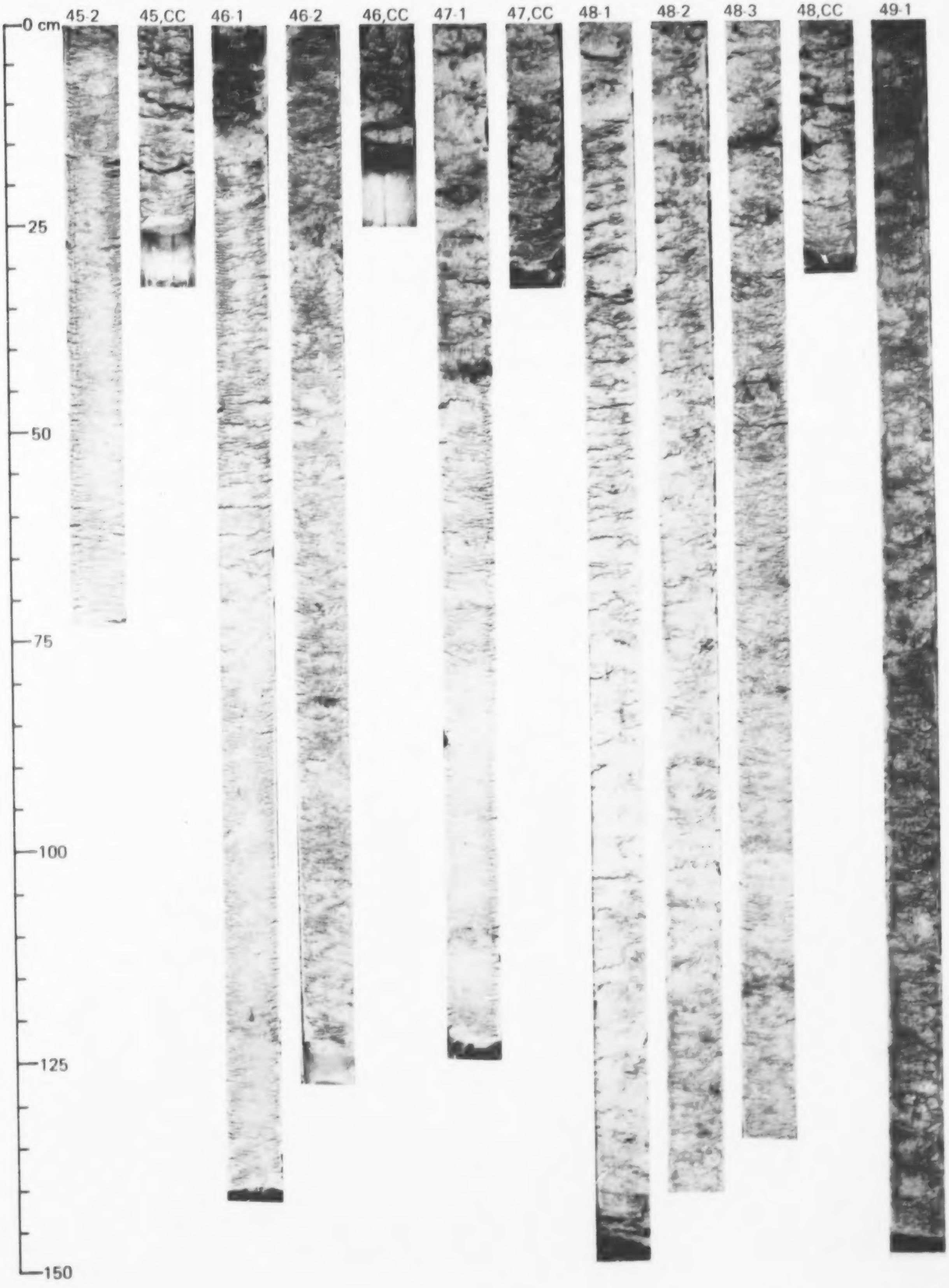
42-4
42,CC
43-1
43-2
43,CC
44-1
44-2
44,CC
45-1


45-2
45,CC
46-1
46-2
46,CC
47-1
47,CC
48-1
48-2
48-3
48,CC
49-1
0 cm
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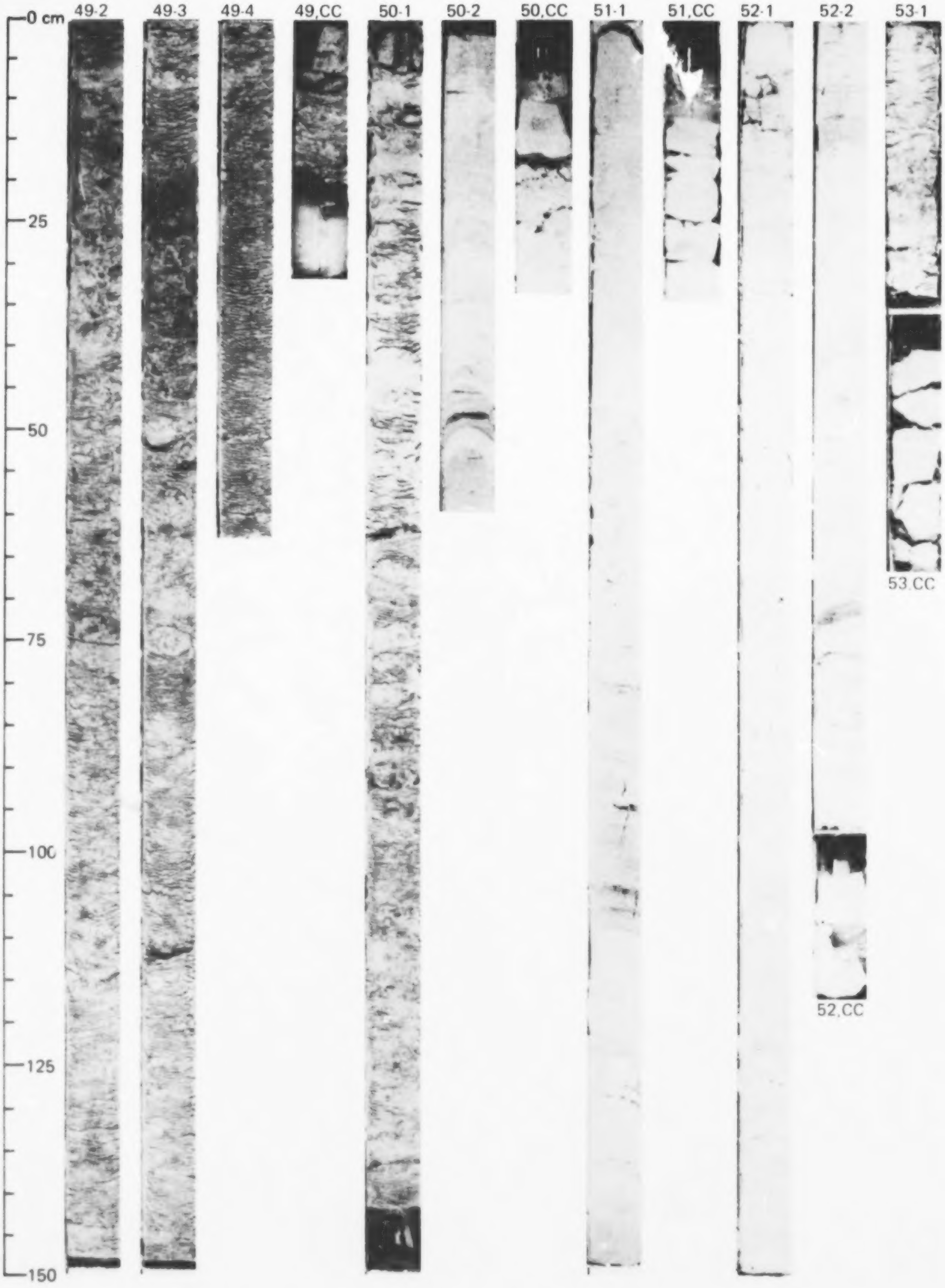
50
75
100
125
150


0 cm
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49-3
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50,CC
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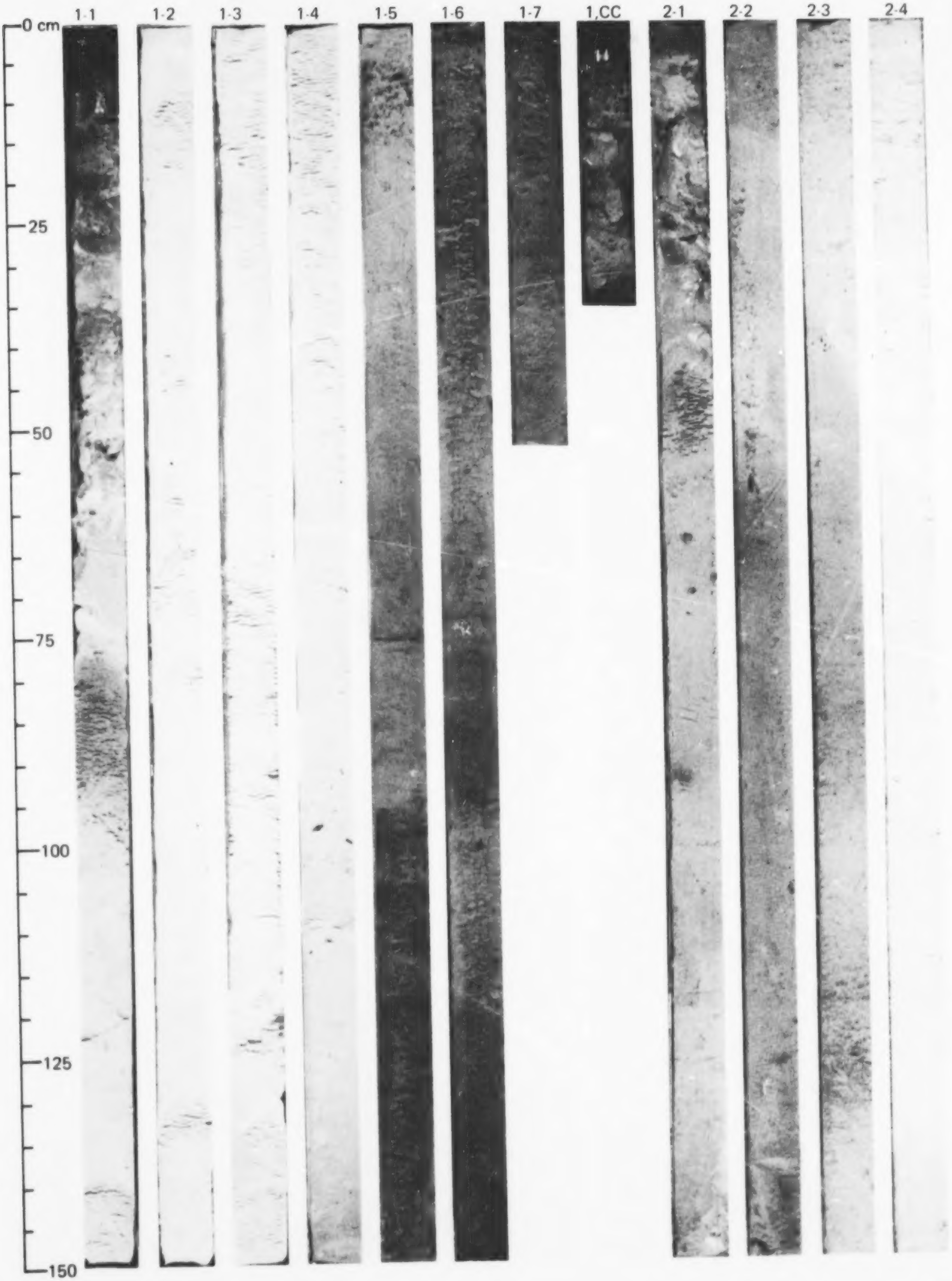
52-2
52,CC
53-1
53,CC


0 cm
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75
100
125
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1-2
1-3
1-4
1-5
1-6
1-7
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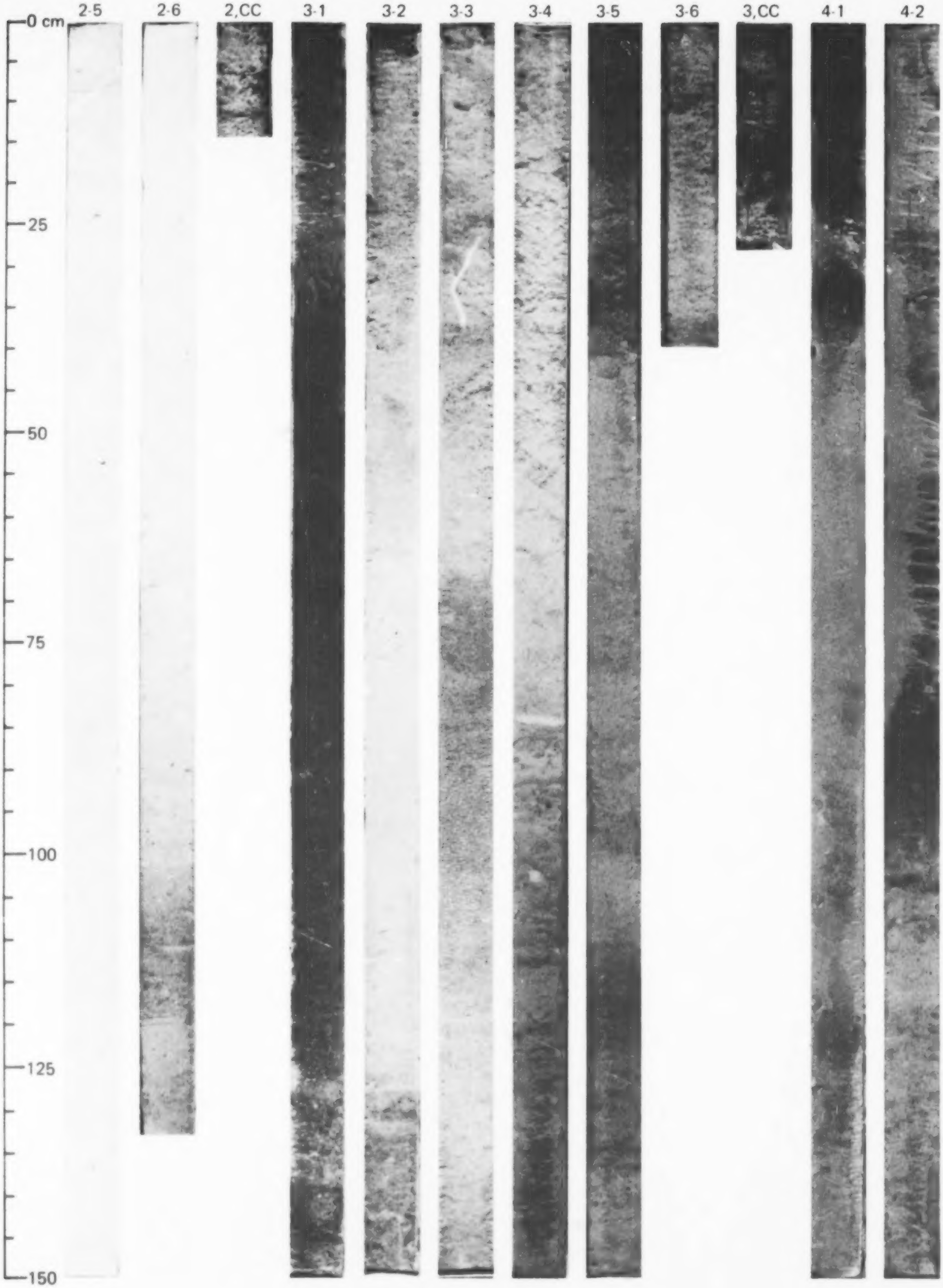
2-1
2-2
2-3
2-4


2-5
2-6
2,CC
3-1
3-2
3-3
3-4
3-5
3-6
3,CC
4-1
4-2
0 cm
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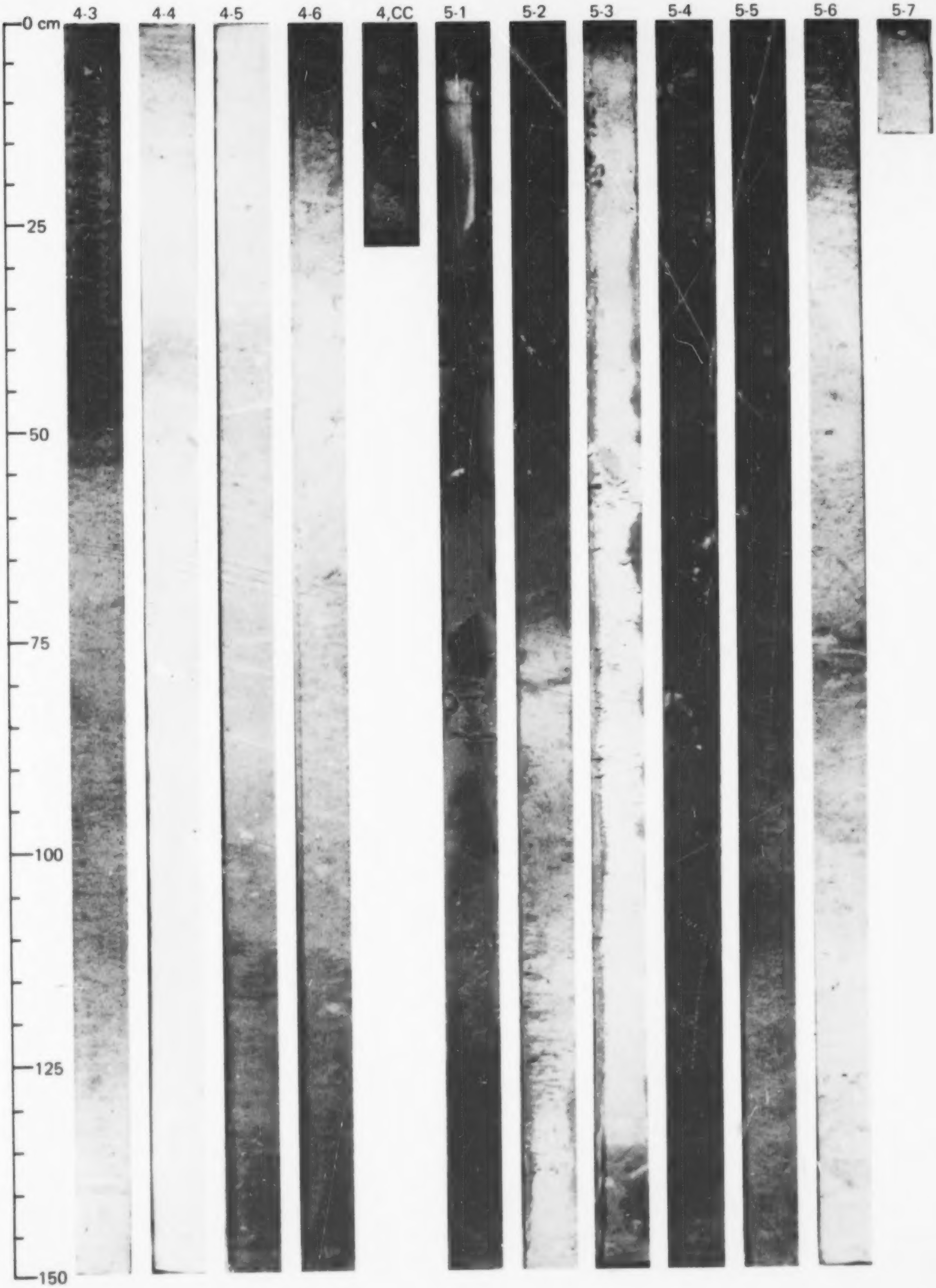
75
100
125
150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100
125
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4-3
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4-6
4,CC
5-1
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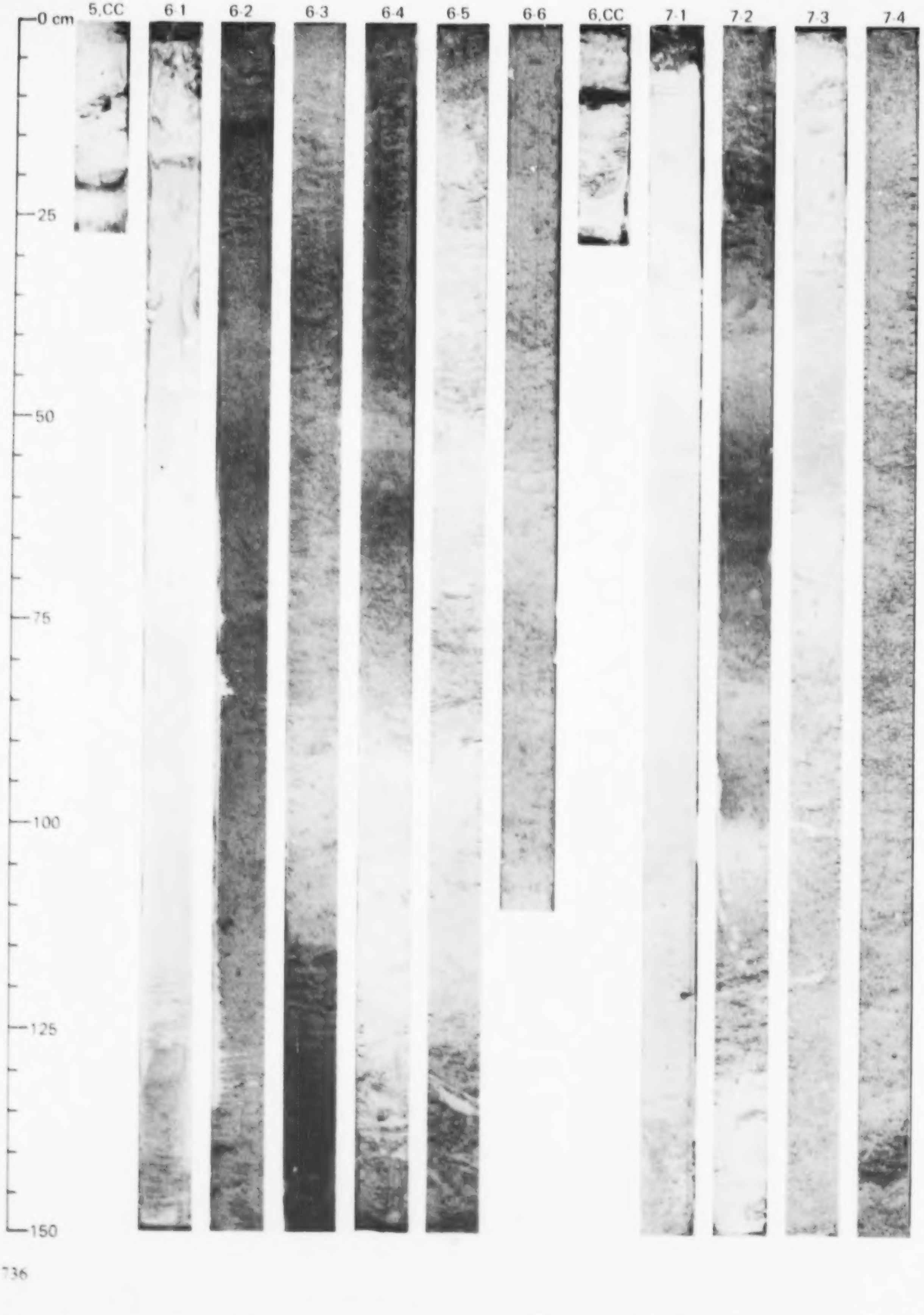
5-3
5-4
5-5
5-6
5-7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125
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6-5
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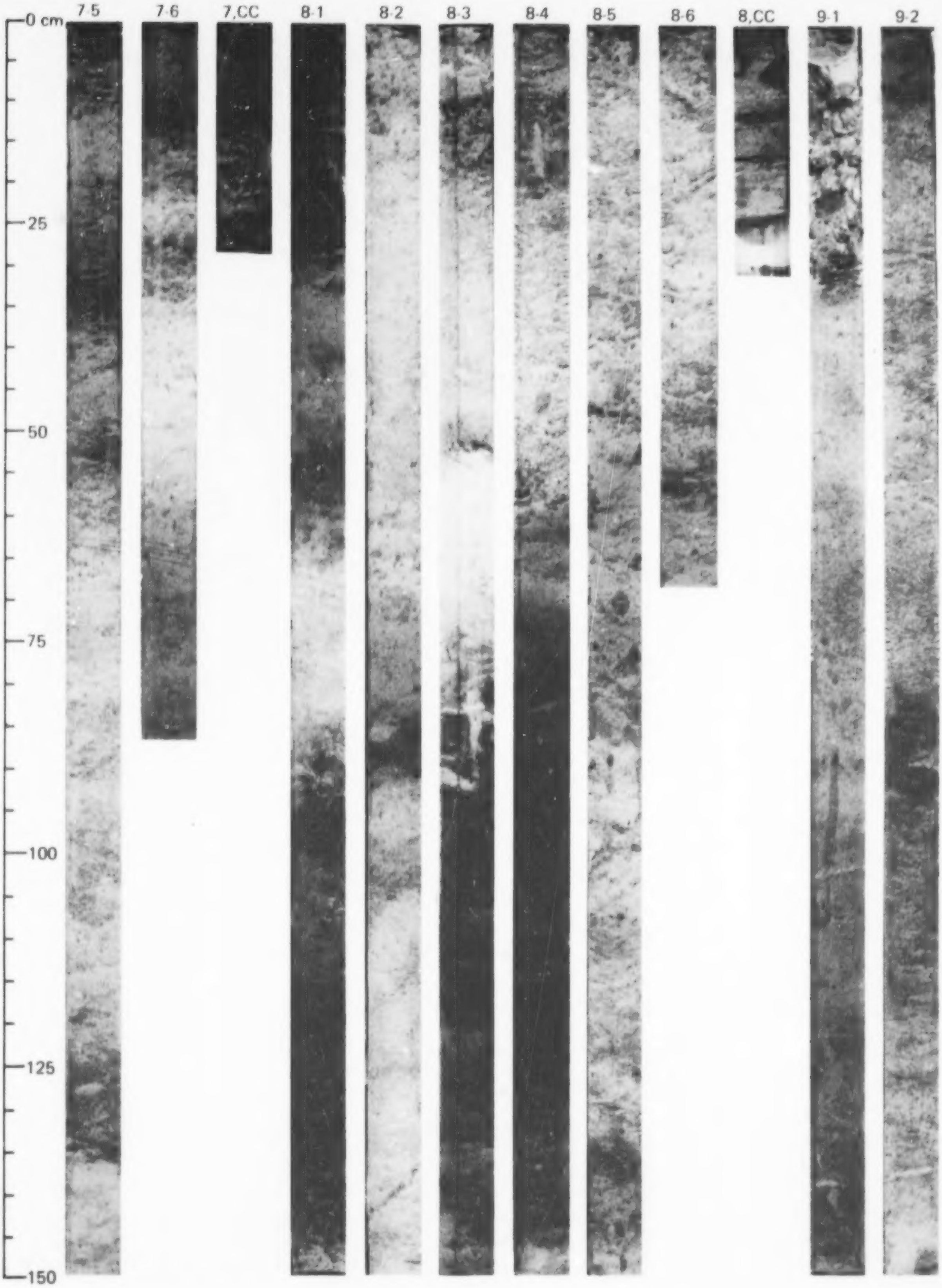
7-1
7-2
7-3
7-4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125
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7-6
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8-1
8-2
8-3
8-4
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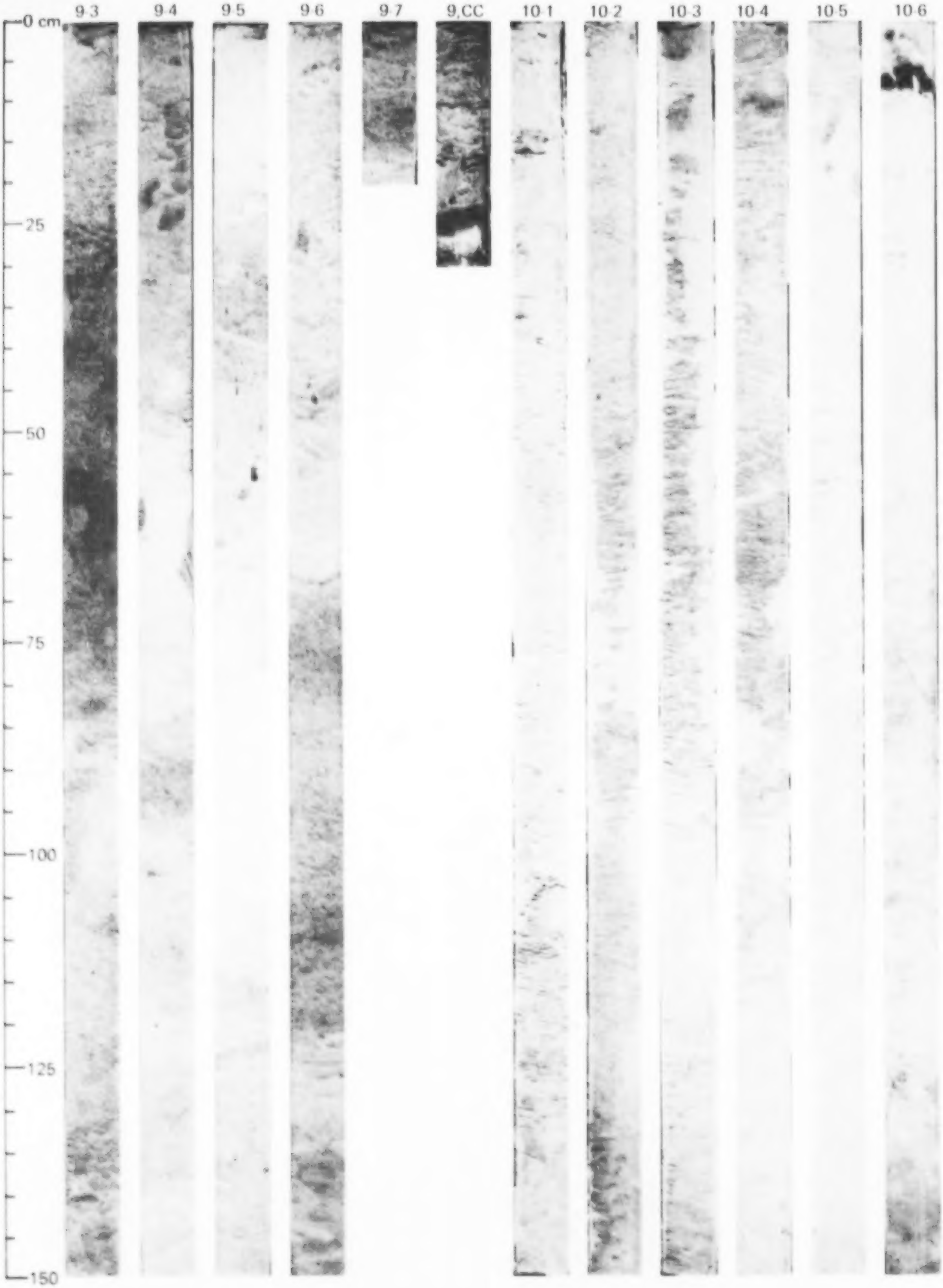
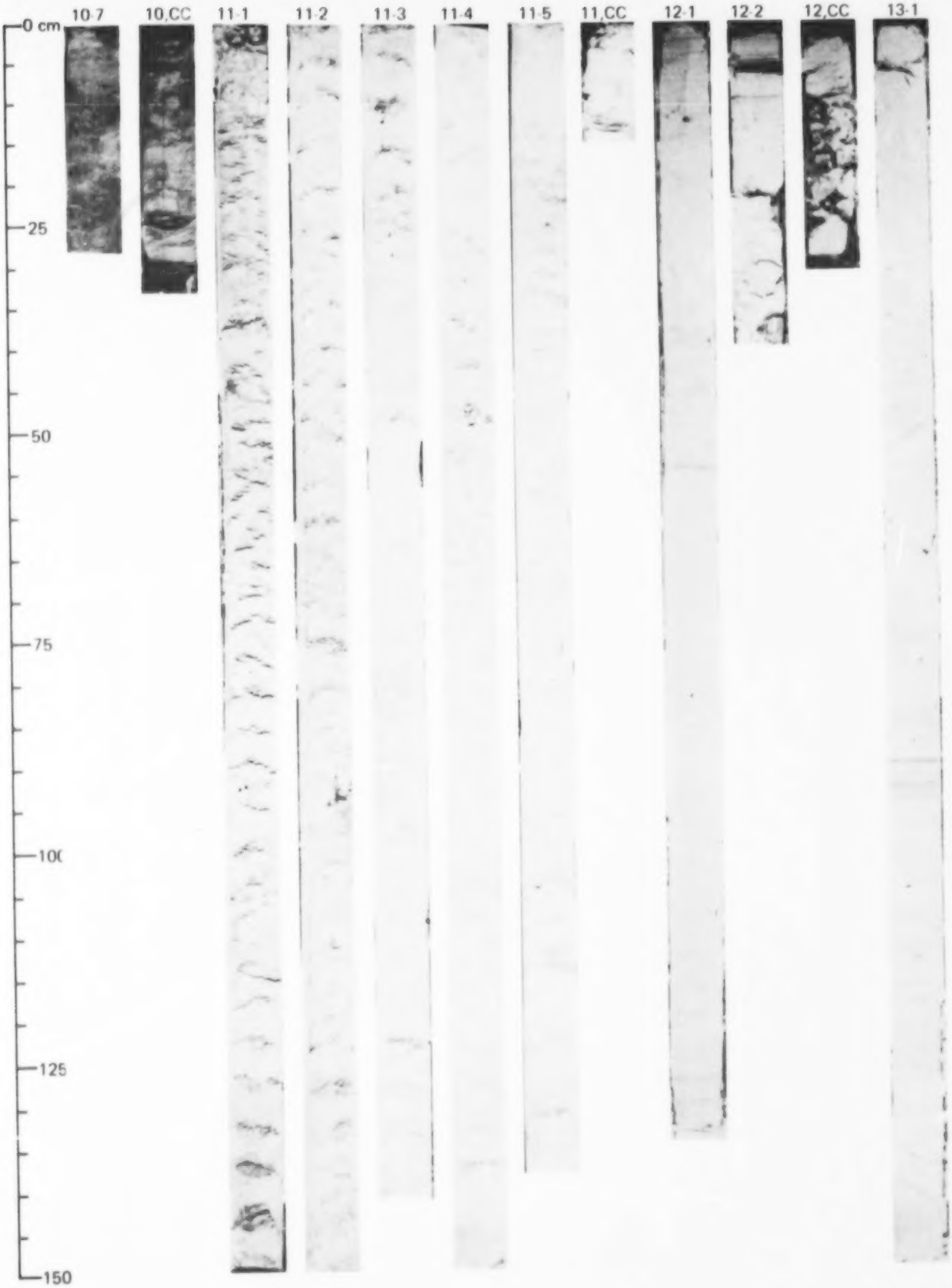
8-6
8,CC
9-1
9-2


9-3
9-4
9-5
9-6
9-7
9,CC
10-1
10-2
10-3
10-4
10-5
10-6
0 cm
25
50
75
100
125
150


10-7
10,CC
11-1
11-2
11-3
11-4
11-5
11,CC
12-1
12-2
12,CC
13-1
0 cm
25
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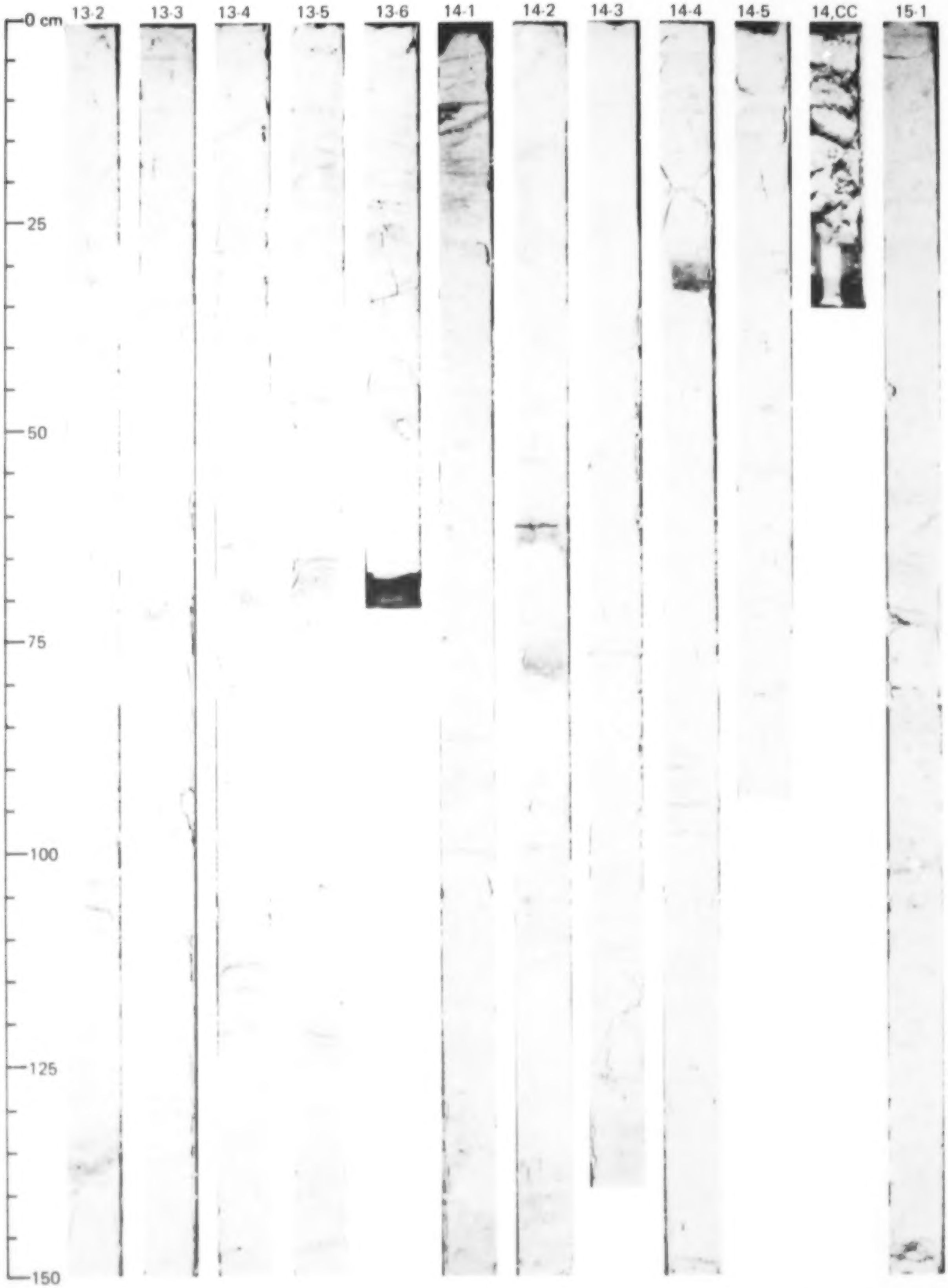
100
125
150


0 cm
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50
75
100
125
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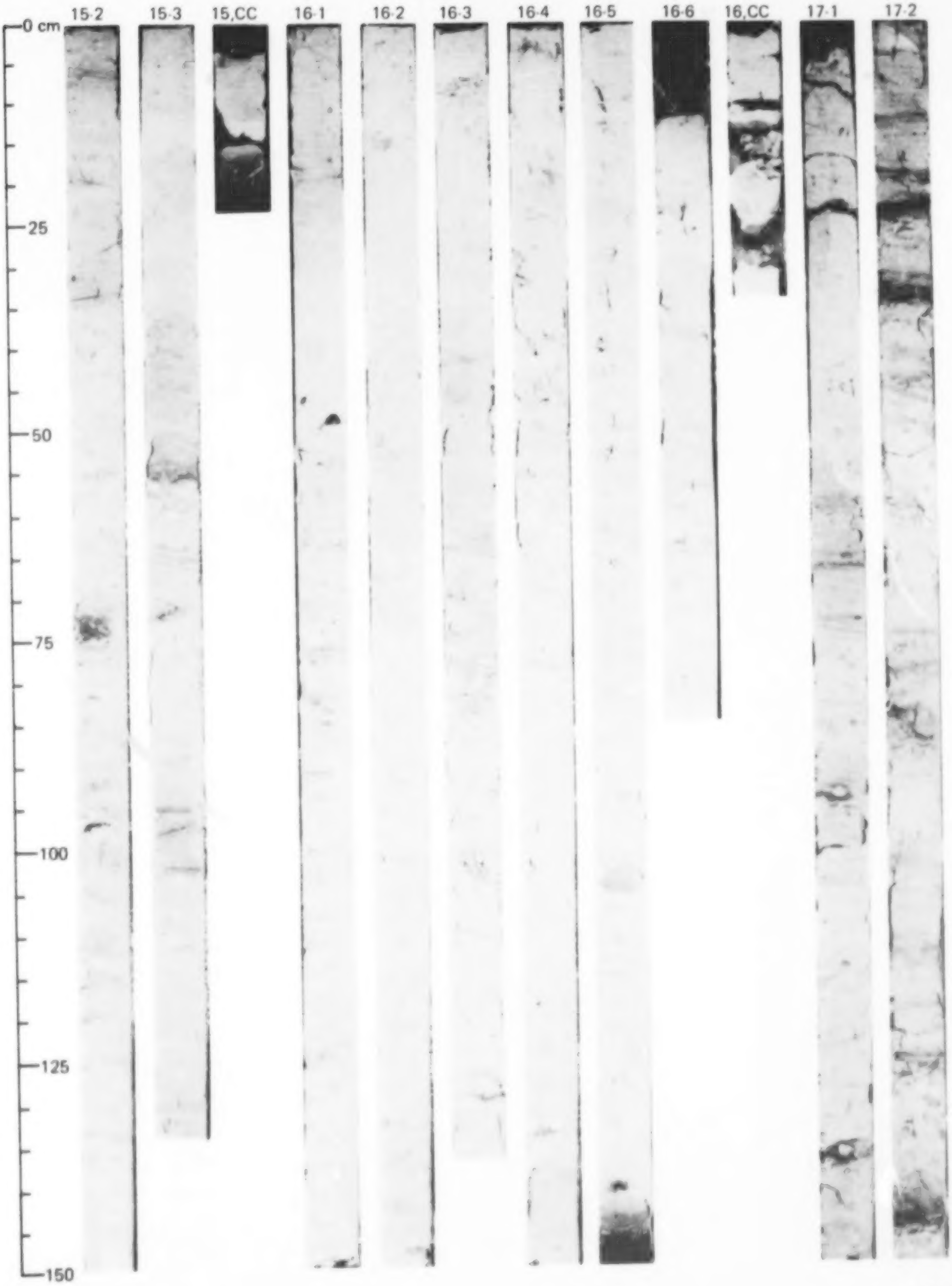
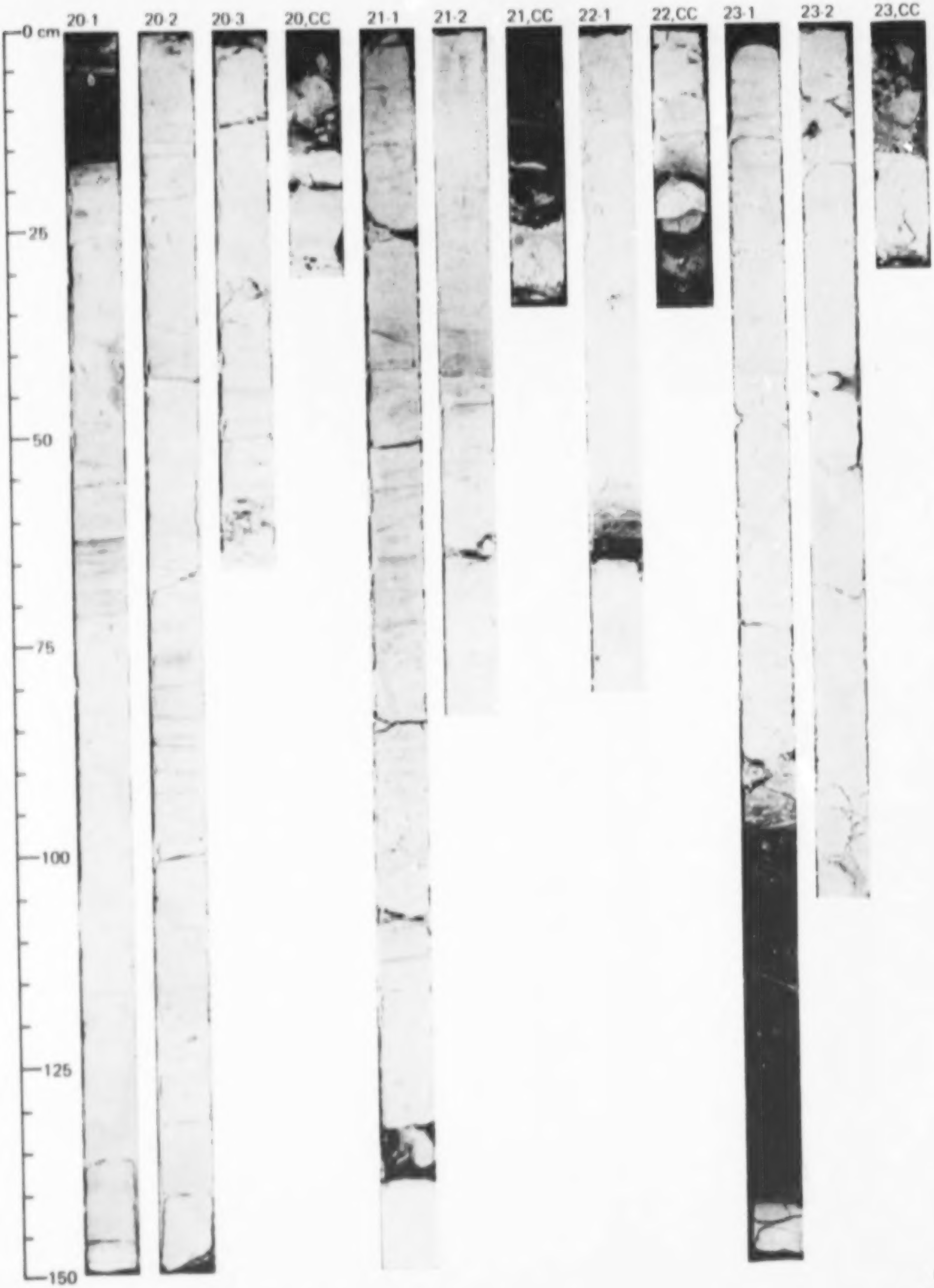
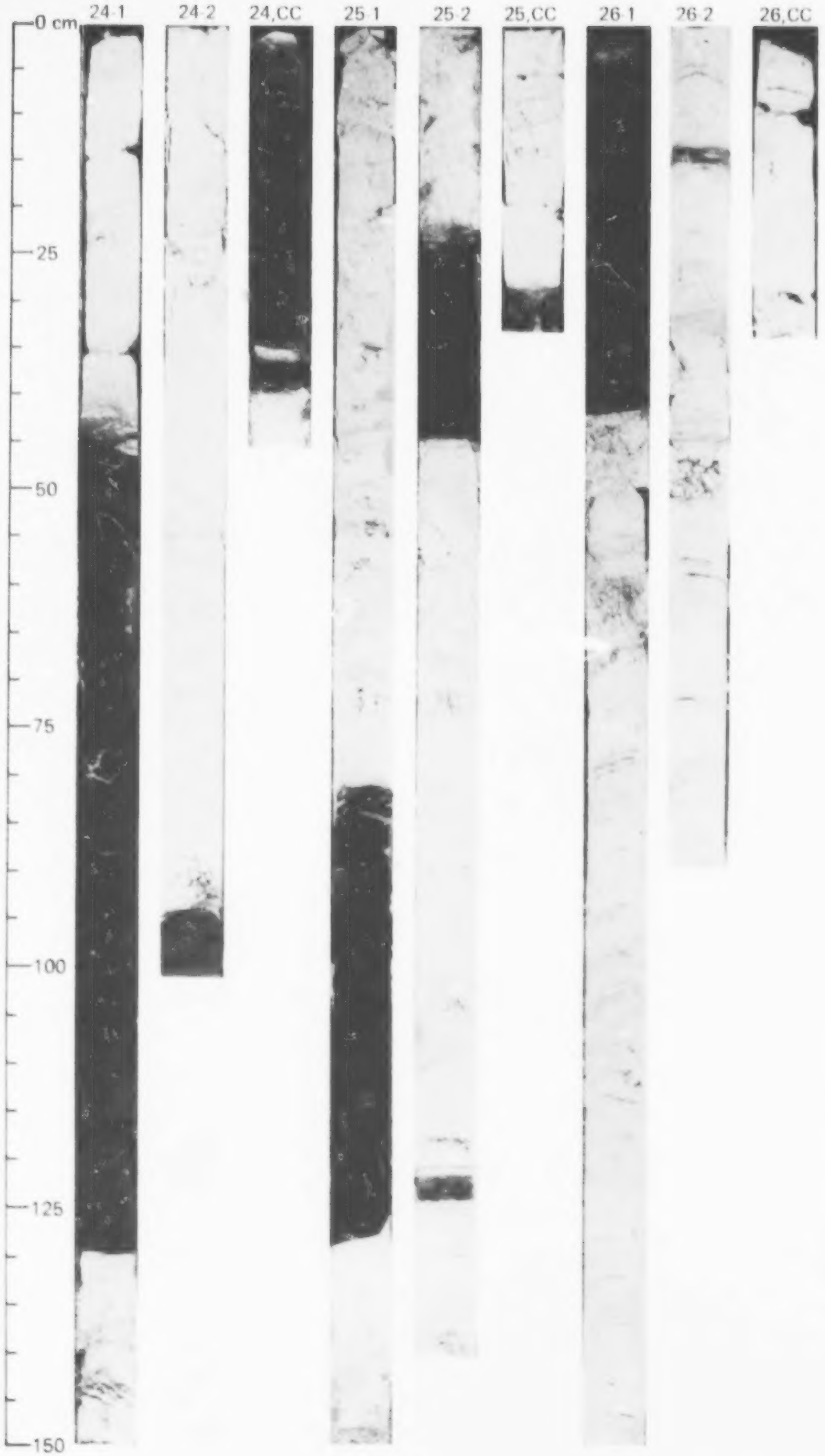
13-2
13-3
13-4
13-5
13-6
14-1
14-2
14-3
14-4
14-5
14,CC
15-1


15-2
15-3
15,CC
16-1
16-2
16-3
16-4
16-5
16-6
16,CC
17-1
17-2
0 cm
25
50
75
100
125
150

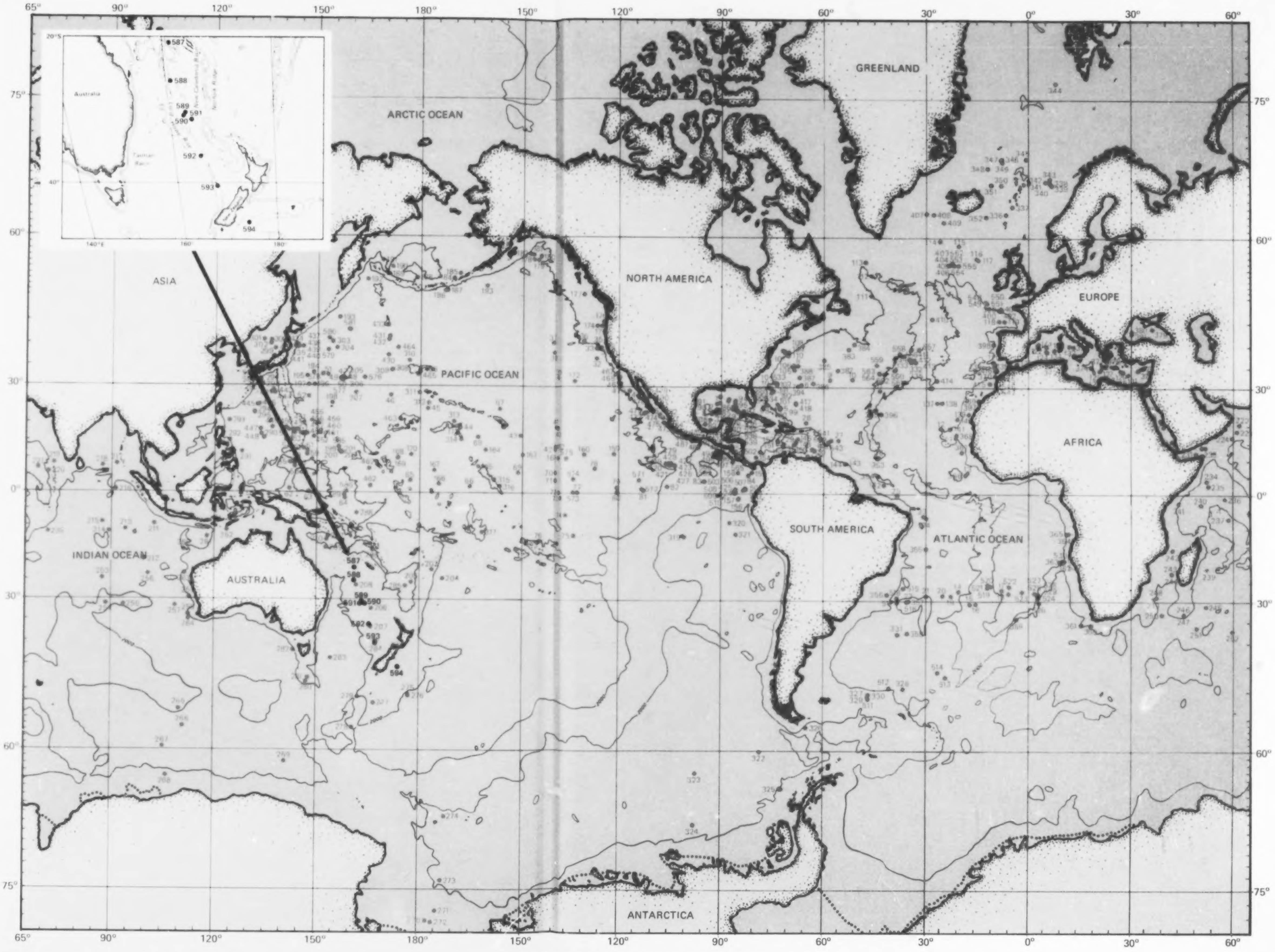
17-3
17-4
17-5
17,CC
18-1
18-2
18-3
18-4
18,CC
19-1
19-2
19,CC
0 cm
25
50
75
100
125
150


20-1
20-2
20-3
20,CC
21-1
21-2
21,CC
22-1
22,CC
23-1
23-2
23,CC
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
24-1
24-2
24,CC
25-1
25-2
25,CC
26-1
26-2
26,CC

Drilling locations

Leg	Location	Sites
Phase 1 1968–1970		
1	North Atlantic	1–7
2	North Atlantic	8–12
3	South Atlantic	13–22
4	Central Atlantic	23–31
5	North Pacific	32–43
6	North Pacific	44–60
7	Central Pacific	61–67
8	Central Pacific	68–75
9	Central Pacific	76–84
Phase 2 1970–1972		
10	Gulf of Mexico	85–97
11	North Atlantic	98–108
Re-entry trials		109–110
12	North Atlantic	111–119
13	Mediterranean	120–134
14	Central Atlantic	135–144
15	Caribbean	146–154
16	Central Pacific	155–163
17	Central Pacific	164–171
18	North Pacific	172–182
19	North Pacific	183–193
20	North Pacific	194–202
21	Coral Sea	203–210
22	Indian Ocean	211–218
23	Arabian Sea	219–230
24	Indian Ocean	231–238
25	Indian Ocean	239–249
Phase 3 1972–1975		
26	Indian Ocean	250–258
27	Indian Ocean	259–263
28	Antarctic	264–274
29	Tasman Sea	275–284
30	South Pacific	285–289
31	North Pacific	290–302
32	North Pacific	303–313
33	North Pacific	314–318
34	South Pacific	319–321
35	South Pacific	322–325
36	South Atlantic	326–331
37	North Atlantic	332–335
38	Arctic	336–352
39	Atlantic	353–359
40	South Atlantic	360–365
41	South Atlantic	366–370
42A	Mediterranean	371–378
42B	Black Sea	379–381
43	North Atlantic	382–387
44	North Atlantic	388–392
44A	North Atlantic	393–394
IPOD I 1975–present		
45	North Atlantic	395–396
46	North Atlantic	396A–396B
47	North Atlantic	397–398
48	North Atlantic	399–406
49	North Atlantic	407–414
50	North Atlantic	415–416
51A	North Atlantic	417–417A
51B	North Atlantic	417B–417D
52	North Atlantic	417D–418A
53	North Atlantic	418A–418B
54	Central Pacific	419–429
55	North Pacific	430–433
56	North Pacific	434–437
57	North Pacific	438–441
58	North Pacific	442–446
59	North Pacific	447–451
60	North Pacific	452–461
61	Central Pacific	462
62	North Pacific	463–466
63	North Pacific	467–473
64	Gulf of California	474–481
65	Gulf of California	482–485
66	Central Pacific	486–493
67	Central Pacific	494–500
68	Central Pacific	502–503
69	Central Pacific	504–505, 501
70	Central Pacific	506–510, 504B
71	South Atlantic	511–514
72	South Atlantic	515–518
73	South Atlantic	519–524
74	South Atlantic	525–529
75	South Atlantic	530–532
76	North Atlantic	533–534
77	Caribbean	535–540
78	North Atlantic	541–543, 395A, B
79	North Atlantic	544–547
80	North Atlantic	548–551
81	North Atlantic	552–555
82	North Atlantic	556–564
83	Central Pacific	504B
84	Central Pacific	565–570
85	Central Pacific	571–575
86	North Pacific	576–581
87	North Pacific	582–584
88	North Pacific	581
89	Central Pacific	585–586, 462A
90	South Pacific	587–594



DEEP SEA DRILLING PROJECT